SERIES H. No. 11. SEASONS, 1921–1929.

UNIVERSITY COLLEGE OF WALES,
ABERYSTWYTH.

WELSH PLANT BREEDING STATION.

Grazing and Manurial Trials on Permanent and Prepared Swards.

AND

Factors Affecting Seed Production of Red Clover.

PRICE 3/6.

1930.
W. B. WALKER, PRINTER, SHREWSBURY.

1,000 6/30.

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PREFATORY NOTE.

The first three articles in this bulletin are a further contribution to our knowledge of pastures in relation to methods of defoliation and intensity of grazing, and with particular reference to the application of manures, including incremental doses of an inorganic nitrogenous fertilizer. The fourth article is included here for convenience, and deals with certain factors influencing seed production in red clover. The question of seed production both of the grasses and clovers is one which is now receiving detailed consideration at the Station, and a considerable amount of useful information which will form the subject of subsequent publications is being obtained.

The three articles concerned with the management of pastures refer to preliminary experiments in this field—experiments which are at present being followed up by trials of a more elaborate nature, supported by a more elaborate technique.

The question of technique is so important that it appears desirable in this prefatory note to allude in a little detail to the methods now adopted for conducting botanical analyses on herbage. As the work of the Station has progressed it has become increasingly patent to us that the only really satisfactory method of making such analyses is one based on productivity, that is to say, one which gives results which can be stated in terms of what precisely is offering to the grazing animal. To ascertain exact percentage productivity for all the contributing species of a bulk sample of course involves laborious separation of each species contributing to such a bulk sample. This is a perfectly feasible procedure, and is one that has been adopted in connection with a large number of experiments that have already been reported upon, and is being adopted in the case of others still in progress. The work demands a high standard of training on the part of the assistants concerned, and a large staff of such assistants.

As the standard of training and of skill increased, it became possible, however, to adopt an estimation method. At first this method was largely tested against results from complete separations, and individual assistants had to prove their competency by actual results before being considered qualified to estimate ; the whole work of course being in charge of those who had previously served a long apprenticeship in the hard school of actually separating.

In work of the sort here under review there is no occasion for anybody to be profoundly interested in differences of the order of 2 or 3 per cent., and indeed, in most grassland treatments, unless changes in species contribution of the order of 5 per cent. and upwards have been brought about, they are not of much economic significance. As a matter of fact, however, our best trained estimators dealing with the same sort of material all through a season will be within 2 per cent. or so of results obtained by laborious separations. This means that the field of research can be greatly extended without the necessity of employing assistants by the hundred—and such is the diversity of the factors influencing grassland that we cannot hope to get very far unless the researches are wide flung, and made to embrace numerous types of grassland and numerous schemes of treatment. It is worth remarking also that these estimations are

based on no conventions, and their absolute accuracy is not contingent upon the correctness of any scientific hypothesis or assumption—their degree of accuracy is always amenable to direct tests.

The trials which have formed the subject of the first article were planned by Mr. William Davies, and during the first year were under his supervision. In order to maintain chronological order in the presentation of results it has been necessary to publish this paper during Mr. Davies's absence in New Zealand, and his name has not appeared as one of the authors, since, of necessity, there has been no opportunity for Mr. Davies to express his views or to read the proof sheets—the Station is, however, greatly indebted to him for his important share in this and other very similar work.

It is a pleasure once more to express thanks to Mr. Fagan for his hearty co-operation in so many aspects of the grassland investigations in progress: and it is of course solely on account of this co-operation that the trials conducted by the Station as such can be supported by chemical researches.

Thanks are due to Mr. Martin G. Jones, who initiated the sheep grazing experiment, and who is no longer on the staff of the Station, for co-operating in the writing up of the trial in question and for assistance given in the second year of its conduct.

The Station is indebted to Mr. T. E. Jones, Mr. I. G. Lewis and Mr. J. L. Rees (now on the staff of the Waite Agricultural Research Institute, Adelaide), for help in connection with the botanical estimations, which have provided so much of the data drawn upon. Thanks are abundantly due to the Rt. Hon. the Earl of Lisburne, on whose farm one of the trials was conducted, and who kindly provided the necessary fencing; to Professor J. J. Griffith, B.Sc., Director of the College Farm (Nantcellan); also to the following farmers: Messrs. J. Davies (Lletyevanhen); J. M. Edwards (Nantsiriol); J. James (Lluest); Hugh Jones (Pensarn); T. Jones (Moelglomen), and W. J. Jones (Rhoscellan), all of whom have given the Station the necessary facilities for conducting trials on their land.

I am personally indebted to Miss Rhoda Jones for seeing this bulletin through the press.

R. G. STAPLEDON.

AGRICULTURAL BUILDINGS,
ABERYSTWYTH,
June, 1930.

THE YIELD OF SHARPLY CONTRASTING PASTURE TYPES AND THEIR RESPONSE TO MANURES.

BY

R. G. STAPLEDON, M.A., AND M. T. THOMAS, B.Sc.

INTRODUCTION.

A considerable amount of evidence has been collected at the Station relative to the yield of pure species cut as pasture grass. For comparative purposes in connection with the investigations on the improvement of grassland it has therefore seemed desirable to endeavour to obtain a rough estimate of the yielding ability of ordinary swards representing sharply contrasting types. The experiments here dealt with constitute preliminary trials conducted with a view to this end. While setting up the trials which involved fencing off small experimental areas it seemed worth while also to test the response of the types selected to simple schemes of manuring, with rather particular regard to the effects of nitrogen when applied as an inorganic fertilizer in incremental doses.

Types of grassland were selected at elevations ranging from practically sea level to about 1,000 ft. The lowland centres represented (*a*) the best valley permanent pastures in the Aberystwyth district: (*b*) inferior pastures containing a large percentage of bent: (*c*) temporary leys on fertile loams and on poorer soils. These leys were in their third harvest year (at the commencement of the experiment). The upland centres represented (*a*) open-hill fescue—*Agrostis* pasture carrying a light covering of bracken and almost devoid of legumes: (*b*) hill fescue pasture more sheltered and at a lower elevation than above, and (*c*) hill "intake" pasture.

The present report deals primarily with two experiments, a main one and a supplementary one; data are, however, also available from other trials, and these latter data are drawn upon in connection with some of the topics under discussion. The main trial was started in the spring of 1927 and was continued on the same plots until April, 1929 (for two complete growing seasons). A supplementary trial which was only maintained for one year was started in the spring of 1928. The plots for the supplementary trial were laid down on the same fields as were those for the main trial—the supplementary was therefore practically a replication of the main trial, although it was not laid down at all the centres.

MATERIAL AND METHODS.

Three plots were set up at each centre, each plot was 6 ft. by 6 ft., and the three were enclosed by a single fence 30 ft. long, 10 ft. wide and about 4 ft. 6 in. high. This allowed 4 ft. between adjacent plots and 2 ft. between plot and fence.

The treatment of the plots was as follows:—

I. Main trial—started spring, 1927.

(*a*) Control—no manure.

(*b*) Phosphate in annual doses of 2 cwt. superphosphate (16% P_2O_5) per annum and potash, one dose of 4 cwt. kainit (20% K_2O).

(*c*) As (*b*) with the addition of nitrogenous manure in periodic (approximately monthly) doses to equal about 100 lb. nitrogen per annum, applied in 1927 partly as sulphate of ammonia and partly as nitrate of soda, and in 1928 wholly as nitro-chalk.

II. Supplementary trial—started spring, 1928.

(*a*) Control—no manure.

(*b*) Phosphate, one dose of 2 cwt. superphosphate (16% P_2O_5).

(*c*) As (*b*) with the addition of nitrogenous manure in periodic doses to equal about 100 lb. nitrogen per annum applied as nitro-chalk.

At the commencement of the experiment all plots and borders were cut and old foggage removed. During the growing season the produce was cut as nearly as possible at the beginning of each month (May 1st to October 30th). The winter growth (November 1st to April 30th) was allowed to accumulate and then cut.

The cutting implements were shears and clippers. After cutting, the produce was put in scrim bags. It had been previously found that a 2 lb. sample of pasture grass will air-dry adequately even in such a wet year as 1927, and in a humid climate such as West Wales possesses. This procedure, largely adopted at the Station, has proved very successful, and consists in hanging the green samples in their scrim bags on poles out in the open. If a little attention is paid to shaking the bags occasionally, it is possible to make good air-dried fodder with practically no discoloration of the produce. Some of the mid-season cuts gave a bulk considerably in excess of 2 lb. green fodder, and in these cases the sample was split and several scrim bags used to dry the grass.

Having regard to the large amount of work entailed, it was impracticable to separate out in detail each individual species and, therefore, in all cases the estimation method of percentage productivity—a method previously employed at the Station for hay samples—was used for botanical analyses. The procedure is as follows: the sample designed for analysis is divided into 10 sub-samples, each sub-sample being as nearly as possible representative of the whole. Each sub-sample is then allotted a total of 10 marks, and these marks are distributed among the species present in the sample according to the estimated abundance (by weight) of the individual species present. The total marks (10 sub-samples) allotted to such species give the estimated percentage productivity of the contributing species.

Discussion of Results.

The whole aim of the experiment under discussion, as already emphasized, was to obtain preliminary data relative to types of grassland *qua* types of grassland, and not to compare the yields of different fields *qua* fields. All that is claimed is that each 6 ft. by 6 ft. square did in fact represent, and truly represent, a particular type of pasture with its characteristic botanical composition (which composition was assessed with a very considerable degree of comparative accuracy). The fact that the control plots, small as they were, were not replicated on each field does not, therefore, by any means render the

comparisons between types and elevations that are here made of no quantitative significance. The data presented, however, are of course only to be regarded as a first endeavour to give a quantitative interpretation to differences that qualitatively have long been recognized as very considerable: while all will admit that some knowledge of the order of magnitude of the difference in yielding ability of types of grassland is essential as a preliminary to detailed researches on many aspects of pasture problems.

The lack of replication obviously detracts appreciably from the weight that can legitimately be attached to the results given by the various manurial dressings.

The areas for fencing were, however, very carefully chosen to be as uniform as possible, and of course the manured and control plots were very close together. In so far as the comparisons of the influence of manures between type and type are concerned it must, however, be remembered that here again we are dealing with widely different swards, and that all the yield data are supported by botanical estimations, while the yields for the different years can very properly be averaged. In many cases the differences to be discussed are so great that there can be little doubt as to the broad implications of the results.

On the face of it, it may seem rather ridiculous to give the yields in terms of lb. per acre—they have, however, to be reduced to some common denominator, and to have set them out on a percentage or any other basis would have added nothing to their accuracy, while it is always desirable to present figures in a familiar guise.

Not for a moment must it be supposed that the yields obtained by a system of monthly cutting with shears would be the same as those that might have been obtained by a method of sampling in front of grazing animals: nor must it be supposed that the botanical re-adjustments would be the same.* In this connection we need only repeat that the experiment was designed to open a campaign on an unexplored subject, and, despite its obvious limitations as to technique, the campaign has, we think, been successfully opened. The evidence here presented is in fact parallel with that at first obtained in the realm of pure species when data were collected on single plants and on small drills—data which, as a matter of fact, have served as a sure foundation for all the subsequent investigations on grassland conducted at the Station.

In matters of this sort—where the factors affecting the major problem are of such complexity—it is very much a matter of being able to walk moderately well before one can usefully attempt to run, and consequently the evolution of a technique that shall be manageable and also do justice to all the factors in their natural operation must inevitably be an exceedingly slow process.

The yields in the majority of the tables which follow are given in terms of "eatables." By "eatables" are to be understood green grass, green legumes and the green foliage of weeds: that is to say, herbage that it might be expected animals would select from if grazing the plots. In these yields moss and the burned or dried leafage of grass and other plants have been ignored. With reference to moss and "burn" it should be remarked that the yields of these two items are affected to some slight extent by adhering dust and inert matter—but not to an extent which would have influenced the general trend of the striking results which will be presented relative to these non-eatables.

* A large series of trials are now in progress with a view to ascertaining yields when animals are the defoliators.

Average figures from a number of centres are chiefly considered in the pages which follow, the evidence showing that such averaging truly represents the general behaviour on each of the swards contributing to the average results. In one set of experiments a potassic manure was used in conjunction with the phosphatic manure. A critical examination of the whole of the data does not, however, reveal any striking difference between the general influence of PK or of P as such on the one hand, or of PKN or PN as such on the other hand. In order, therefore, not to burden this paper with excess of tables (and unnecessary tables at that), the P and PK plots have been averaged together, as have the PN and PKN plots. In the tables the figures are given under C (=control), PK and PKN. The notation PK and PKN has been adopted in preference to P and PN, because the larger proportion of the data was obtained on plots subjected to the former scheme of manuring.

The issues raised by the data collected from these experiments are of a varied nature, and will be dealt with under a number of appropriate headings.

The Comparative Yielding Ability of Pastures of Different Types.

The data presented in Table I are averaged from all the trials giving evidence as to the yielding ability of pastures of different types. In most cases the figures are the average of yields for more than one year. The influence of manures as such is for the moment not under consideration: but in order to add a greater measure of reliability to the comparisons made the yields are given for each centre, (*a*) on the basis of the average of such control (unmanured) plots as are available, and (*b*) on the basis of the average of the manured with the unmanured plots. A brief statement is also made as to the character of each sward and as to its salient botanical characters.

When comparing these yields it must be remembered that the defoliation was drastic (cutting to ground level with sheep shears even only monthly being probably more severe than any normal intensity of grazing), and, as will be shown in a subsequent section, such a system of cutting was harder on the temporary leys and best permanent pastures than on the poorest swards. Nevertheless the yield from the best ley and best permanent pasture was eight times as great as from the poorest hill centre, while if any particular year is considered we find in 1927 the yield (unmanured) at Foel was only 5.2 cwt. (cwt.=100 lb.) per acre, which was only one-fourteenth of the best lowland yield for that year. It is evident, therefore, that pastures differ very widely in their yielding ability, and perhaps this is seen even more strikingly if we confine attention only to the four lowland permanent pastures—all on good grass producing soils.

The yield from Nantcellan with good quantities of rye-grass and cocksfoot was 51 per cent. greater than that from Rhoscellan, the sward of which was practically devoid of rye-grass and cocksfoot—figures which strongly suggest that the botanical composition of the sward exerts a very decided influence on its yielding ability. Indeed a comparison of the yield at Nantcellan with that of the three other lowland permanent pastures affords further evidence in the same direction, and certainly indicates that large contributions of miscellaneous weeds are not compatible with high pasture yields.

The much lower yields from the upland than from the lowland permanent pastures must of course be in a large measure due to exposure and to the poorer and more impoverished soils at the high elevations. It is equally obvious in the last resort that botanical composition, as the figures in the tables indicate,

TABLE I.—*To show average yield as pasture grass (catables) per annum in cwt. (=100 lb.) per acre of air-dry fodder from swards of different types for (a) the average of the unmanured plots, and (b) the average of the manured and unmanured plots taken together. Particulars are also given of the salient characteristics of the swards.*

Centre and height above sea level.	Pasture type and soil.	Salient botanical characteristics in approximate percentages.	Number of years averaged.	Yields. Control plots only.	Yields. All plots
Lowland centres.					
Nantcellan 100 ft.	Permanent. Heavy clay.	Perennial rye-grass 19 : cocksfoot 19 ; dogstail 13 : bent 14 ; fog 13 : legumes 6 : miscellaneous weeds 8.	Two (1927—29)	65.2	71.1
Nantsiriol 50 ft.	Permanent. Sandy loam.	Perennial rye-grass 16 : bent 23 : fog 12 : dogstail 12 : legumes 4 : miscellaneous weeds 23	Two (1927—29)	43.2	51.8
Rhoscellan 250 ft.	Permanent. Heavy loam.	Bent 26 : fog 12 : dogstail 10 : sweet vernal 12 : legumes 18 : miscellaneous weeds 6.	Two (1927—29)	38.4	47.1
Brook Field 250 ft.	Permanent. Badly drained.	Dogstail 13 : rough-stalked meadow grass 10 : fog 14 : legumes 14 : miscellaneous weeds 26.	One (1928—29)	41.3	43.0
Bank 400 ft.	Temporary. Thin stony, shallow loam.	Cocksfoot 37 : perennial rye-grass 28 : legumes 20 : rough-stalked meadow grass 6 : miscellaneous weeds 4.	Two (1927—29)	43.9	61.4
Crosswood 300 ft. (Perennial rye-grass)	Temporary. Rather heavy loam, probably derived from river alluvium.	Perennial rye-grass 45 : legumes 27 : rough-stalked meadow grass 21 : miscellaneous weeds 4.	One (1928—29)	70.5	68.0
Crosswood 350 ft. (Cocksfoot)	Temporary. Rather shallow, medium loam.	Cocksfoot 46 : legumes 26 : rough-stalked meadow grass 13 : miscellaneous weeds 1.	One (1928—29)	56.0	60.5
Upland Centres.					
Foel 850 ft.	Permanent. Light loam.	Bent 37 : fog 10 : sweet vernal 11 : legumes 5. miscellaneous weeds 14.	Two (1927—29)	16.5	28.0
Pensarn 750 ft.	Permanent. Loamy but peaty.	Bent 25 : fine-leaved fescue 33 : moss 16 : legumes 2 : miscellaneous weeds 16.	Two (1927—29)	13.2	22.3
Llety 900 ft. (Fine-leaved fescue)	Permanent. Dry peat.	Fine-leaved fescue 36 : bent 18 : moss 21 : legumes nil : miscellaneous weeds 21.	Two (1927—29)	9.0	21.5
Llety 900 ft. (*Molinia*)	Permanent. Peat.	*Molinia* 40 : moss, dead and dry grass 51 : fine-leaved fescue 5 : legumes nil : miscellaneous weeds 2.	One (1928—29)	8.4	27.0

has had an immense influence on the relative yielding abilities of uplands and lowlands. Experiments now in progress have been designed to throw further light on the relative influence of species *qua* species, elevation (=largely exposure) *qua* elevation, and soil type *qua* soil type. This much can, however, already be said that one of the Station's pedigree strains of cocksfoot has been doing exceptionally well on the uplands.

The most interesting comparison is that between the temporary leys and the lowland permanent pastures. The "perennial rye-grass" ley at Crosswood was on a soil type no more favourable to grass production (judged by permanent grass adjoining the ley) than that at Nantcellan—yet on average figures the advantage in yield appeared to be with the ley. This particular ley was put down with one of the simple mixtures that have proved uniformly successful in all our trials. The mixture consisted of 3 lb. Italian rye-grass: 12 lb. perennial rye-grass (indigenous cleaned from wild white clover), 4 lb. rough-stalked meadow grass and 3 lb. wild white clover. This particular field (18 acres) from the outset was a signal success and developed almost immediately into a first-class "permanent pasture." The "cocksfoot" ley at Crosswood was sown in a mixture as above, except that indigenous cocksfoot replaced the perennial rye-grass—the soil was not as deep as on the "rye-grass" ley, but yet the yields from this ley were in excess of those from all the permanent pastures except that at Nantcellan.

In some respects the results from the ley on the Bank (Plant Breeding Station Farm) were the most remarkable, for this ley was sown on a very thin, stony and shallow soil, and yet on average figures it was giving quite as much, and probably rather more, pasture grass per annum than the permanent pastures other than that at Nantcellan.

These results from the leys are the more noteworthy when it is realized how comparatively weedless were their swards in comparison with those of the permanent pastures, and when it is reiterated that the system of cutting was by no means such as to favour the leys.

The Seasonal Productivity of Lowland and Upland Pastures compared without regard to the Influence of Manures.

The results from typical centres have been averaged and presented in Table II in a manner which is self-explanatory. Before considering the results in detail it must be borne in mind that the cuts were monthly (and although drastic compared to ordinary grazing, were not nearly as drastic as if the cuts had been fortnightly), and that the cutting was not started early in the spring. The seasonal distribution is seen to be relatively even from May to August—as previous data have shown it always is when cutting is not started too early in the spring.

The lowland permanent pastures (averaged) contained a considerable amount of perennial rye-grass and white clover: the lowland ley consisted predominantly of cocksfoot and perennial rye-grass and wild white clover, while in the upland pastures bent and fine-leaved fescues predominated, the leguminous flora being of the slightest.

The lowland ley and the lowland permanent pasture in the main behaved in a very similar manner, both giving a high primary peak in May and a high secondary peak in August. The ley gave both higher absolute and relative yields in May than the permanent sward, due almost certainly to a much higher proportion of cocksfoot in the former. The amount of winter keep provided

TABLE II.—*To compare the seasonal productivity of lowland and upland pastures. The actual yields (as eatables) are given for each cutting (in cwt. of 100 lb. air-dry fodder per acre) and also the percentage of the total yield for the whole year. The figures are for the average of the two seasons* 1927—28 *and* 1928—29. *Only the unmanured plots are here considered.*

	May.	June.	July.	Aug.	Sept.	Oct.	Winter.*	
Lowland permanent pasture average of 3 centres ..	10.5	7.0	10.5	10.5	4.5	1.3	6.1	Yield.
	21.0	14.0	21.0	21.0	9.0	2.0	12.0	Per cent.
Upland permanent pasture average of 3 centres ..	2.0	3.5	3.7	1.7	1.2	0.3	0.9	Yield.
	15.0	26.4	27.8	12.8	9.0	2.2	6.8	Per cent.
Lowland temporary ley; 1 centre, the Bank†	12.1	7.2	7.7	12.0	5.0	2.2	5.5	Yield.
	23.5	13.9	14.9	23.3	9.6	4.2	10.6	Per cent.

* November 1st to April 30th.
† The only ley from which two seasons' data were available.

by both ley and permanent sward is noteworthy, being as high as 11 per cent. (on the average of both permanent pasture and ley) of the total produce of the year.

This figure affords an interesting quantitative statement of the extent to which pastures can maintain winter growth in a humid locality not normally subjected to very severe winters. That the permanent swards gave a slightly higher winter yield than the ley was probably due to the much more exposed position of the ley and the very much poorer soil. Indeed it is surprising that the ley compared so well with permanent pasture: that it did so was undoubtedly largely due to the good amount of perennial rye-grass which it contained.

At every cutting date the yield from the upland pastures was far below that from the lowland. The seasonal distribution was also different; thus, the percentage contribution to total yield made by the May cut was not much more than half that of the lowland centres. This affords a quantitative estimate of the lateness with which the upland pastures start growth in the spring—and this, despite the fact that these swards contained a very small proportion of legumes (always late starters), while legumes were well represented in the lowland swards. The upland pastures did not attain to their maximum productivity until July: relatively they maintained productiveness through

TABLE III.—*To show the average yields of eatables as air-dry fodder in cwt. (= 100 lb.) per acre for upland and lowland centres under the influence of manures in comparison with control plots. The figures are average yields from the results of two seasons, except in the case of Crosswood, from which centre data for 1928 only are available.*

	PKN.	PK.	C.
Lowland—Permanent Pastures.			
Nantcellan	82.3	65.8	65.2
Nantsiriol	65.8	46.0	43.6
Rhoscellan	55.7	48.4	40.3
Average	67.9	53.4	49.7
Relative with PKN as 100	100.0	78.5	73.0
Lowland—Temporary Pastures.			
The Bank	68.4	54.5	43.9
Crosswood*	73.7	62.2	70.5
Crosswood†	70.3	50.8	56.0
Average	70.8	55.8	56.8
Relative with PKN as 100	100.0	79.8	80.4
Upland—Permanent Pastures.			
Foel	41.0	26.3	16.5
Pensarn	37.7	16.1	13.2
Llety	41.7	13.8	9.0
Average	40.1	18.7	12.9
Relative with PKN as 100	100.0	46.7	32.2

* Mixture on deep, rich soil with perennial rye-grass the chief contributing species.
† Mixture on shallower soil, with cocksfoot the chief contributing species.

September and October as well as the lowland pastures. The winter yield of the upland swards was about one-sixth that of the lowland; the upland swards also produced an altogether smaller proportion of their total yield in winter than did the lowland pastures.

The lateness with which the upland swards start growth cannot be regarded as only due to exposure and climatic conditions as such, for bent (wherever it grows) is always a late grass—the poor winter productivity is probably chiefly, though by no means entirely, due to exposure and climate. The paucity of perennial rye-grass of course makes for rather poor winter growth, but, on the other hand, both bent and fine-leaved fescues under exceptionally favourable conditions are capable of appreciable winter growth, while the fescues, given suitable conditions, are competent to make a good showing early in the spring.

The Influence of Manures on the Gross Yield of Pastures of different Types.

Average figures as to yield of eatables under manures are set out in Table III. The most striking result is the much greater proportional increase in yield under PKN at the uplands than at the lowlands—the amount of fodder produced

under complete dressings at the uplands being as great as that produced at some of the lowland centres without manures. This in itself is significant, having regard to the vast difference between rental values of upland and lowland farms. An interesting feature in respect of the uplands is the fact that these swards have responded relatively better to PK than have those of the lowlands, despite the fact that a leguminous flora on the former swards was well-nigh negligible on the control plots. This latter happening is, however, in part to be accounted for by the fact that the upland swards had probably never previously received any manurial dressing of any kind, while all the lowland swards would have been dressed with basic slag at some time or another previous to the setting up of these experiments.

The difference between the uplands and the lowlands will be referred to in greater detail in a subsequent section.

The temporary leys show certain interesting features: the fact that there was no difference between the PK and control plots was almost certainly because each of the leys received a good dressing of basic slag at the time of sowing out, so that the PK was supplementary to an initial foundation of P. It is important to note that the best ley (the perennial rye-grass ley on fertile soil at Crosswood) gave no definite response to PKN. Here we had vigorous-growing species on a highly fertile soil subjected to a drastic system of cutting—conditions which gave no scope for added benefits from nitrogen, a point which will also be dealt with in more detail in a subsequent section. The ley on the poorest soil (the Bank), although consisting of vigorous species, would appear to have responded in a quite definite manner to nitrogen, as did all the permanent

TABLE IV.—*To show the effect of manures on grasses, clovers, weeds, moss and burned herbage on pastures of different types. The figures are given as percentage estimated contribution to the total herbage produced per grazing season.*

Plot.	*Grasses.*	*Legumes.*	*Weeds.*	*Moss and burned leafage.*
Lowland—Permanent Pastures (Average of three centres for two years).				
PKN	93.0	1.6	4.8	0.6
PK	73.7	16.9	8.6	0.8
C	71.7	13.1	12.8	2.4
Upland—Permanent Pastures (Average of three centres for two years).				
PKN	86.5	1.0	6.7	5.8
PK	66.8	7.2	10.9	15.1
C	58.2	1.7	16.3	23.8
Lowland—Temporary Leys (Average of two centres, one for two years and the other for one year only).				
PKN	91.3	4.8	3.4	0.5
PK	69.6	26.3	3.5	0.6
C	71.1	23.5	4.7	0.7

pastures. Indeed, having regard to the drastic nature of the cutting, the response given by the permanent pastures is higher than might perhaps have been expected.

In this connection it is, however, to be noted that bent (*Agrostis*) contributed in greater or lesser degree to all the permanent pastures ; it should be noted also that whereas without manures the best ley outyielded the best permanent sward, with manures the best permanent pasture gave a substantially heavier yield than the best ley : the truth being that permanent pastures withstand drastic defoliation better than the highly productive leys.

The Effect of Manures on the Contribution of Grasses, Clovers, Weeds, Moss and Burned and Dried Herbage to Swards of Different Types.

The results from the various centres have been averaged in appropriate groups, and the figures are given in Table IV.

The figures for the control plots show that excessive amounts of moss and burned herbage are present on the upland swards, and that these are negligible in quantity on the lowland temporary leys, while the moss on the lowland permanent pastures is relatively slight. One of the most striking effects noticeable on the uplands was the remarkable diminution of moss and burned herbage under PKN, to which the figures bear ample witness. PK has also effected a decided diminution, but the addition of incremental doses of nitrogen has greatly accentuated this beneficial result—a result which has been equally apparent under both ammonium sulphate and nitro-chalk.

As has been previously remarked, the contribution of legumes to the upland swards was very slight. Wild white clover was present in large amount on the temporary leys and in good amount on the permanent pastures.

The relative increase of legumes (chiefly wild white clover) under PK has been in inverse proportion to the amount originally present in the swards,* being negligible on the temporary leys and very great on the upland pastures.

PKN at every centre has substantially increased the percentage of grasses, very appreciably reduced the percentage of weeds, and caused a really remarkable diminution in the amount of legumes.

Once more it must be remembered that the defoliation was drastic and that there was no treading due to grazing animals. The figures are, however, important in themselves for all the plots were treated alike, and they show that added nitrogen has a remarkable capacity for reducing leguminous herbs under conditions the direct opposite of those which obtain on meadows (in the sense of hay and aftermath-producing swards). Evidence from experiments still in progress shows that the retardation of wild white clover and other leguminous herbs under the influence of nitrogen is not nearly so great when a proper system of controlled grazing is adopted, but if the grazing is unduly intensive we have data which suggest that very substantial retardation takes place.† These facts relative to leguminous herbs are significant, but they represent only a small portion of the data now being accumulated on the all-important relation of grasses to clovers under different systems of manuring and management. This is a question which will be dealt with in detail in a subsequent report from the Station.

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* cf. Stapledon (1).

† See Jones and Jones (p. 38 of this bulletin).

TABLE V.—*To show the estimated percentage contribution of individual grass species to the aggregate herbage cut as pasture for two seasons under different manurial treatments for swards of contrasting types.*

Species.	Upland swards (3 centres).			Lowland pasture. (2 centres).			Lowland ley (1 centre.)		
	PKN	PK	C	PKN	PK	C	PKN	PK	C
Perennial rye-grass	1.0	Trace	—	37.4	24.4	23.9	32.9	20.3	16.4
Cocksfoot	—	—	—	3.4	2.4	0.3	35.6	28.3	26.4
Crested dogstail	6.0	1.8	2.8	18.8	14.2	11.4	Trace	0.1	0.5
Rough-stalked meadow grass	0.1	—	—	7.3	4.1	2.3	8.7	4.4	4.3
Fine-leaved fescue	32.5	33.5	25.4	4.1	3.1	2.9	0.2	1.8	2.2
Bent	35.1	20.3	20.9	7.1	8.9	10.3	0.8	0.3	2.6
Yorkshire fog	10.2	4.0	3.6	8.9	11.7	12.6	6.8	5.0	5.2

The Influence of Manures on the Various Grass Species Contributing to Swards of Different Types.

Table V affords material for examining the influence of manures on individual grass species. No single grass species has reacted to manures in the striking manner in which legumes have responded, positively to PK and negatively to PKN. At the lowlands the effect of PKN has been materially to increase valuable species like perennial rye-grass, cocksfoot and rough-stalked meadow grass, both on the ley and permanent pastures, while its influence on the less-to-be-desired species (under conditions favourable to good swards) fine-leaved fescue, bent and Yorkshire fog has been on the balance rather to reduce than to increase them.

On the uplands all grasses have been increased by the application of PKN. Most interesting is the quite decided increase shown by Yorkshire fog—a grass which on swards of this degree of poorness should be regarded as a welcome addition to the fine-leaved fescues and bent. The fact that perennial rye-grass became definitely recognizable in the bulk herbage under PKN at some of the upland centres is probably not without significance, and it will be of interest to watch the further behaviour of this species on the intensively manured plots.

Seasonal Productivity on Swards of Various Types under the Influence of Manures.

Before discussing seasonal productivity under the influence of manures in terms of gross yield per month, it will facilitate a proper understanding of the matter if, first, we consider the seasonal productivity of legumes, weeds and grasses as such.

Legumes and Weeds.—The data set out in Table VI provide the material for an appreciation of the position in so far as legumes and weeds are concerned. Legumes were not present to a sufficient extent at the highlands to provide any useful evidence as to seasonal productivity.

The figures, taken as a whole, estimates though they be, tend to show and indeed to emphasize, how largely wild white clover actually contributes to the eatables on good lowland pastures and on good temporary leys. The data tend

TABLE VI.—*To show the estimated percentage contribution of legumes and weeds to the monthly cuts and to the winter period from swards of different types under different systems of manuring. The figures therefore show relative seasonal productivity.*

		May.	June.	July.	August.	September.	October.	Winter.
		Legumes.						
Lowland pastures	Control ..	24.2	30.8	28.5	20.7	28.5	5.2	8.8
	PK.. ..	16.5	24.8	32.3	25.6	40.0	6.2	8.7
	PKN ..	4.0	4.7	4.7	1.0	1.5	1.0	1.0
Lowland temporary ley ..	Control ..	4.0	32.9	29.4	45.0	41.4	4.5	2.5
	PK.. ..	6.0	36.5	35.5	47.5	47.0	13.0	16.5
	PKN ..	2.0	12.5	7.0	3.5	4.5	1.0	2.5
		Weeds.						
Lowland pastures	Control ..	8.3	9.8	8.7	5.7	14.5	7.0	11.0
	PK.. ..	8.2	5.0	5.7	3.2	2.7	4.0	13.5
	PKN ..	5.5	4.3	6.7	5.5	6.2	2.0	17.5
Lowland temporary ley ..	Control ..	3.5	3.0	3.0	2.0	2.5	6.5	4.5
	PK.. ..	3.5	1.5	2.0	1.0	5.0	4.5	6.5
	PKN ..	3.0	3.0	1.5	3.5	3.5	4.5	1.5
Upland pastures	Control ..	—	19.2	16.8	27.7	13.0	11.3	17.6
	PK.. ..	—	10.0	8.0	15.3	10.5	9.8	10.7
	PKN ..	—	6.8	7.3	16.8	6.3	11.2	9.7

further to emphasize the lateness with which white clover starts abundant growth in the spring; by October 1st the white clover contribution has fallen very sharply, while the amount of eatables afforded by white clover in the winter is very slight. In contrast to the legumes, the seasonal productivity of weeds is seen to be much more uniform throughout the growing season—the weed contribution being well maintained into October. The most interesting comparison is, however, that for the winter period, when the weed contribution on lowland permanent pastures far exceeds that of the legumes on similar pastures, while on the uplands we have a substantial weed contribution to the eatables offering compared to practically nothing from the legumes.

These facts may well be of very decided significance when it is remembered that legumes give a decidedly higher silica-free ash than do grasses. There is evidence to show that many weeds also have a higher silica-free ash than the grasses; it is, therefore, very important to ascertain the mineral content of weeds giving green and eatable leaves in the case of all such species as are definitely palatable to sheep in the winter and early spring, that is to say, when there is a leguminous shortage in the eatables offering. This is a matter now under detailed study at the Station.

In so far as manures are concerned, the most striking thing is the extent to which PK carries heavy clover production right through July and August, while the peak of clover yield actually shows itself in the September cut on the

lowland pastures, and is distributed between the August and September cuts on the lowland leys. The very high clover figures for June, July, August and September cuts are particularly to be noted both on the control and PK plots, for they will be shown to have a very decided influence on seasonal production of total eatable fodder. Under PKN not only is clover very greatly reduced, but such clover as is developed falls away in yield very rapidly after the July cut. The relative paucity of weeds on the lowland temporary ley is typical of scores of plots which have been put down with simple mixtures. The effect of PKN, as before stated, has been to reduce weeds, but not materially to affect their relative seasonal productivity.

The Grasses.—The influence of manures on the grass species can best be shown by giving short notes relative to the behaviour of each species.

Perennial rye-grass.—On the lowlands, perennial rye-grass behaved in a very characteristic manner. It gave its highest contribution to the total yield of eatables in May on both manured and unmanured plots. Its relative contribution fell through June and July and into August, but by the cut made on September 1st it was giving as high a contribution as (and in some cases a slightly higher contribution than) in May, and, except where cocksfoot was present, was the highest yielding species on September 1st. At all the lowland centres and on all the plots this species made the highest contribution to winter eatables. The only difference in its behaviour on the permanent pastures and on the leys was that the high secondary peak showed itself on the latter swards in the cut made on October 1st instead of in that made on September 1st. The effect of PKN both on the leys and the permanent pastures was very largely to equalize the relative yield per month of perennial rye-grass from May to October, but even so a secondary peak definitely showed itself in September or October on all the swards under investigation so treated.

At the uplands, perennial rye-grass was only present in negligible amount, except on the PKN plots at one centre, and there it contributed 1.4 per cent. to the eatables in the May cut then dwindled to absolute insignificance throughout the rest of the grazing season, but contributed about 6 per cent. to the eatables offering in the winter. The trend of the data under review is in complete accord with the behaviour of this grass as shown by pure plot evidence, and exhibits it as a species with a tendency to flag in the mid-season and to have an outstanding ability for winter growth and freshness.

Cocksfoot.—This was not a heavily contributing species on the average of the lowland permanent pastures: on these pastures its contribution was relatively very slight in May, but it rose to an important position by July. Under PKN, although perennial rye-grass contributed 32.1 per cent. to the May herbage, and cocksfoot only a negligible amount, yet by the July cut the latter grass was yielding as heavily as the rye-grass. The cocksfoot yield, however, fell away rapidly after the July cut.

On the temporary leys where cocksfoot was present in large amount, its yield was well maintained from May to October: relative to perennial rye-grass it showed to the greatest advantage in the June, July and August cuts. Under PKN cocksfoot attained to its greatest relative prominence in August when, for example, perennial rye-grass was contributing about 20 per cent. to the eatables and cocksfoot about 55 per cent.

The cocksfoot used on the ley in question was a pedigree indigenous strain, and its winter contribution to the eatables was noteworthy—a contribution which was materially assisted by PKN. Thus the winter contribution (under PKN) for perennial rye-grass was 37 per cent. and for cocksfoot 23 per cent. It should be added, however, that the all-the-year-round contribution of cocksfoot to the eatables was about 40 per cent. and of rye-grass about 30 per cent.—none the less the winter figure for cocksfoot, a species generally considered of negligible winter value, is of decided practical significance, and it is a result which appears to be substantiated by trials still in progress.

Crested dogstail.—The seasonal productivity of this grass did not appear to be influenced to any appreciable extent by manures. On the lowland permanent pasture it behaved very like perennial rye-grass, giving a high May and a high October peak of productivity, and falling to a relatively very low position in July. On the lowland temporary ley, where it had made a volunteer appearance, it only made an appreciable contribution to the eatables (about 4 per cent.) in the October cut. On the upland swards, where its contribution on the control plot was less than 10 per cent., it also gave its highest proportional peak in May; it gave a secondary peak in October, but not to the same pronounced extent as on the lowlands. Relative to perennial rye-grass, and relative to the all-the-year-round productivity of the two grasses, crested dogstail did not contribute to the winter eatables to anything like the same extent.

Rough-stalked meadow grass.—This grass, on the lowlands, maintained a fairly uniform relative productivity throughout the growing season with a tendency to reach its highest contribution of eatables in May or June and not to give at all a pronounced secondary peak. Relative to its all-the-year-round contribution, rough-stalked meadow grass gave decidedly satisfactory winter results. Under PKN with an all-the-year-round contribution of about 7 per cent. it contributed about 12 per cent. to the " eatables " of the winter period, which was a much higher relative contribution than on the control plot. Its contribution to the hill pastures was negligible.

Agrostis (*bent*).—Bent grass was only present in negligible amount on the lowland temporary ley. On the lowland permanent pastures with an all-the-year-round contribution of 13 per cent. its contribution to the May cut was too slight to be recorded.

The cut on June 1st revealed this grass as the most highly contributing species on the control and PK plots: under PKN its proportional productivity was about on a par with that of perennial rye-grass. High yields were again recorded in the July cut—thereafter productivity fell away until the October cut, when on the control and PK plots it was contributing more than perennial rye-grass to the " eatables ": on the PKN plots perennial rye-grass and bent contributed equally to the herbage available. Relatively bent did not contribute to the winter period nearly as well as perennial rye-grass or as well as rough-stalked meadow grass, but it did so quite as well as, or even perhaps slightly better than, crested dogstail.

On the hills bent shared dominance with the fine-leaved fescues, but its lateness to start in the spring was further shown, for on the hills the May cut consisted overwhelmingly of fine-leaved fescues, and it was not until the July

cut that bent attained to its full productivity. Under PKN from July onwards and during the winter period the bent outyielded the fine-leaved fescue—such was not, however, the case on the PK and control plots, although on the balance it tended to show the higher winter productivity of the two species. This grass (*Agrostis*) was less productive in 1928 (when the months of April and May were dry) than in 1927.

The fine-leaved fescues.—These grasses did not contribute to the sward under test on the lowlands to a sufficient extent to warrant any conclusions being drawn as to their seasonal productivity. On the uplands, sheep's fescue (*Festuca ovina*), as before stated, shared dominance with bent. Speaking generally, the distribution throughout the growing season was very uniform in the case of this grass. On the control and PK plots there was an appreciable secondary peak of production in September. Under PKN the May cut (early " spring " for the uplands) was greatly in excess of that on the control plot, but no secondary peak showed itself. The winter contribution of the fescues was also greater under PKN than on the other plots.

Yorkshire fog.—On manured and unmanured plots alike, and alike on upland and lowland swards, the relative seasonal productiveness of Yorkshire fog was maintained at a remarkably uniform level, no really pronounced peaks of production being exhibited. Relative to the amount present, Yorkshire fog showed to excellent advantage in the May cut, but only to moderate advantage during the winter period.

TABLE VII.—*To show relatively the seasonal productivity of various pasture types under different manures. The yield (free of moss and burned herbage) under PKN is placed at 100 for each month, and the yield for PK and C respectively calculated to this standard.*

	May.	*June.*	*July.*	*August.*	*September.*	*October.*	*Winter period.*
Lowlands—Permanent pasture (3 centres).							
PKN	100	100	100	100	100	100	100
PK	62.7	78.3	112.6	104.3	79.1	51.4	46.1
C	57.7	68.6	106.3	92.2	84.0	47.7	59.1
Lowlands—Temporary pasture (1 centre).							
PKN	100	100	100	100	100	100	100
PK	65.0	95.8	105.3	106.0	99.9	95.2	79.7
C	54.2	77.0	92.7	86.0	80.9	72.2	55.7
Uplands—Permanent pasture (3 centres).							
PKN	100	100	100	100	100	100	100
PK	31.0	60.9	57.0	46.2	43.6	28.3	19.2
C	15.3	45.0	36.5	24.9	31.7	32.8	16.5

Gross Yield of Eatables.

The figures in Table VII are set out on the basis of placing the yield of eatables for each month under PKN at 100 and calculating the proportionate yields under PK and C respectively to this standard. At the uplands the PKN yield was substantially the heaviest, being at each cut more than double that of the control plot every month, and six times as great during the winter period ; while the PK yields were quite definitely greater than those of the control on every occasion (with the exception of October).

The seasonal productivity at the lowlands will be seen to be in marked contrast to that at the uplands. Both on the lowland pastures and on the lowland temporary ley the PK plots outyielded the PKN plots in July and August, while even the control plot of the permanent pasture gave a heavier yield in July than the PKN plot. In the case of the temporary ley the yield from the sum of the June, July, August and September cuts was practically the same on the PKN and PK plots.

On reference to Table VI it will be apparent that these remarkable yields from the PK plots, in contrast to those from the PKN plots, were due to the excellent response of clovers during July, August and September on the former plots, and to the marked reduction of clover on the latter. Thus, under the drastic system of defoliation adopted, the response made by the grasses to added nitrogen was not sufficient during the period of maximum clover development to compensate for the great reduction in the leguminous contribution to the eatables.

On the uplands, although clovers were greatly increased by PK, the amount of clover (itself small) contributing to the eatables in July and August, even on these plots, was not nearly a sufficient set-off to the enormously enhanced productivity of the grasses when nitrogen supplemented PK.

Under the conditions of this experiment (drastic defoliation without the intervention of animals) the weight of eatables taken in the July cut under PKN was actually as high on the upland as on the lowland swards. This is a fact the implications of which cannot, however, be usefully discussed until evidence from a number of experiments still in progress is available.

The data as a whole here discussed further emphasize the need of adopting a system of grazing that will tend to make for a proper balance between legumes and grasses ; for this is of the first necessity if maximum economic benefits are to be obtained from added nitrogen,* and equally so if the best results are to accrue from the use of phosphatic manures alone.

The influence of season (weather conditions) and of pre-treatment.

At certain centres the experiment was conducted on the same plots through two consecutive seasons (1927 and 1928) on precisely similar lines. At these centres, therefore, if any reduction in yield in the pasture grass of the second year showed itself, such reduction would presumably have been due to the influence of pre-treatment (drastic defoliation) in the first year and (or) to the influence of weather conditions, if these conditions were less favourable to growth in 1928 than in 1927.

All the work so far conducted at the Station on individual species and on

* Equally important with a view to this end is a knowledge of the proper dosage of nitrogen to apply and the most appropriate dates for such applications.

simple seeds mixtures (temporary leys) has shown that drastic defoliation in one year tends to decrease the yield in the next year, and that the reduction in yield is in direct proportion to the severity of such pre-treatment. The present trials are the first of this sort which have been conducted on permanent pastures and consequently, although the data are limited, and, as previously explained, not really satisfactory for a critical comparison of this kind, since a number of replicated plots are not available, it is none the less desirable to examine such evidence as we have, for the very good reason that we do know that "pre-treatment" is an exceedingly potent factor bearing on the management of temporary grass. It is, therefore, of extreme importance to explore the matter—even if only quite tentatively in the first endeavour—relative to permanent pastures also.

The weather.—A synopsis of the weather conditions for 1927 and 1928 respectively is given in Table VIII.

On the balance, 1928 would not be expected to be as favourable to grass production as 1927—chiefly on account of the very dry April and May of the former year. Against the dry April and May of 1928 has, however, to be set the very heavy rainfall of January, and the adequate, or more than adequate, amount recorded each month for the period June to December.

At the best it is an exceedingly difficult matter correctly to assess the precise influence of the weather of one year compared to that of another on the productivity of grass.* To do so with any profound degree of accuracy necessitates a comparison of replicated plots in precisely the same condition (in respect of management, harvest year, pre-treatment and so forth) in each year.

It follows, therefore, that a critical estimate of the influence of weather from year to year is only possible if definite and necessarily complicated experiments are planned for the explicit purpose.

In so far as the two years now under review are concerned, the most reliable data available for comparison are given by a hay and aftermath experiment in which 14 mixtures were involved. The average yield from all the mixtures for each year would certainly deserve to be considered reliable evidence as to yield *qua* yield. A disturbing influence, however, arises from the fact that 1927 represented the first and 1928 the second harvest year—thus, other things apart, there would be a tendency for the second harvest year yield to be lower than that of the first. In the present instance, however, this tendency would certainly not have been very great because (1) the mixtures consisted largely of indigenous strains, and (2) the plots used for the purpose of comparison had received ample dressings of a nitrogenous fertilizer in both harvest years and a good foundation of superphosphate and kainit in the first harvest year.

A comparison between the two years is shown in the statement hereunder :—

Yields in cwt. (=100 *lb.*) *per acre air-dry fodder.*

	Hay.	*Aftermath.*	*Total.*
1927	78.54	15.65	94.19
1928	64.76	30.00	94.76

The figures are interesting in themselves and show that the hay crop of 1928 undoubtedly suffered as the result of the dry April and May of that year,

* See Stapledon (2).

TABLE VIII.—*To show the salient weather conditions for the two years 1927 and 1928.*

		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Rainfall May to Aug. inclusive.
1927	Rainfall in inches	4.4	3.3	3.6	2.1	2.0	5.8	6.0	6.4	6.0	3.8	3.7	2.8	49.9	20.2
	Sunshine in hours	38.7	82.6	92.7	146.7	219.9	172.2	122.0	156.0	106.7	114.5	75.9	33.3	1361.2	—
	Mid-temperature	41.3	40.2	44.3	44.5	51.7	52.7	58.8	58.0	53.8	51.7	44.0	36.3	—	—
1928	Rainfall in inches	7.4	3.8	2.0	1.1	0.7	5.6	3.9	6.7	2.1	6.6	7.0	4.2	51.2	16.9
	Sunshine in hours	51.3	76.9	103.2	147.4	195.1	162.6	201.8	172.8	183.2	111.7	63.0	36.6	1505.6	—
	Mid-temperature	42.1	43.5	42.5	46.5	51.8	53.9	57.3	58.0	54.6	50.8	46.6	39.9	587.5	—

but that under good growing conditions subsequently the aftermath more than made up for the deficiency in hay, and thus the gross yield for the two years was substantially the same. Incidentally these figures confirm previous results indicating that a heavy aftermath frequently follows a poor hay crop, and once more draw attention to the serious question of dealing adequately with aftermath in a humid climate. In the present connection the figures serve to suggest that taking the growing season as a whole 1928 was not less favourable than 1927 for grass production. The effect of a spring drought is usually, however, more marked on pastures than on fields put up to hay, but the only pasture data suitable for comparison are those appertaining to the trials immediately under review. We have two lowland centres* where we can contrast a first year of treatment in 1927 with a first year of treatment in 1928, but unfortunately the May yield at one centre in 1927 was interfered with by sheep breaking into the plots, consequently, the average figures for the two centres can only be given for the period June to October and for the winter. At the uplands we also have two centres available for comparison, but again we are able to consider only the date range June to October and the winter, because in 1927 no May cuts were taken on the hills.

TABLE IX.—*To show* (1) *the yields of eatables per month in cwt.* (=100 *lb.*) *of air-dry fodder, based on the average of the PKN, PK and C plots for the period June—October*; (2) *the aggregate yield for the June—October period, and* (3) *the yield for the winter period respectively for the years* 1927 *and* 1928. *Average figures are given for* (*a*) *two lowland permanent pastures and* (*b*) *two upland pastures.*

Centres.	Year.	June.	July.	August.	September.	October.	Period June-October.		Winter period.
							Weight.	Relative.	
Lowland	1927	7.16	13.06	15.88	4.88	1.39	42.37	100	4.45
	1928	13.74	8.96	7.54	4.06	2.27	36.58	86	7.15
Upland	1927	4.48	5.18	4.11	3.16	0.43	17.36	100	1.83
	1928	5.57	6.93	2.95	1.40	1.38	18.41	100	5.59

The comparative figures given in Table IX are based on the average results of the PKN, PK and C plots. Taking the June to October period as a whole it will be seen that at the lowlands the productivity in 1928 was about 14 per cent. less than in 1927, while at the uplands the former showed to a 6 per cent. advantage. These differences are presumably to be attributed to weather conditions.†

* Unfortunately the experiment was not started a second time (i.e. in 1928) at Nantcellan, which was the most productive of the permanent pastures.

† It will be noted that the June cut was actually higher in 1928 than in 1927, and that it was the cuts of July and August that were most in favour of 1927. It has been previously noted, however, that an early spring drought frequently does not take immediate effect.

The conditions for winter growth at both lowlands and uplands would seem to have been altogether in favour of 1928, but of course the amount of herbage produced in the winter is only a small proportion of that produced during the whole year ; so all in all on the lowlands and under the conditions of defoliation adopted we must regard 1928 as having been less favourable to growth than 1927 ; but taking the whole year round probably not to any greater extent than about 14 per cent.

The effects of pre-treatment will now have to be considered in the light of such evidence as we have been able to produce in regard to influence of weather.

The influence of pre-treatment.—The evidence for Nantcellan (the highest yielding lowland permanent pasture) can be considered from the point of view of all-the-year-round yield, because at this centre the May cut was not interfered with.

In comparing the yields of 1927 with those of 1928 we are here of course dealing with the same plots cut in both years and on a similar basis both years. The statement hereunder provides the data for comparison :—

Yields in cwt. (= 100 *lb.*) *of air-dry fodder per acre at Nantcellan in* 1927 *and in* 1928 *when drastic cutting in the first year was followed by drastic cutting in the second year.*

	PKN		*PK*		*C*	
	Weight.	*Relative.*	*Weight.*	*Relative.*	*Weight.*	*Relative.*
1927 ..	95.67	100	73.29	100	72.50	100
1928 ..	68.85	72	58.30	79	57.35	79

Under each scheme of manuring the yield of the second year (1928) has been considerably less than that of the first, and the reduction has been greater than that (14 per cent.) attributable to the difference in weather conditions. The fact that the reduction in yield under PKN has been greater than under PK and C is worthy of note, and will be referred to later.

The influence of pre-treatment on the less fertile lowland pastures can only be compared for the period June to October, because, as before explained, the May cut was either interfered with or not taken.

TABLE X.—*To show for the average of two lowland and two upland centres the yields in cwt.* (= 100 *lb.*) *of air-dry fodder of eatables per acre for the period June—October in the first* (1927) *and second* (1928) *years of drastic defoliation with sheep shears.*

Centres.	Year.	PKN	Relative.	PK	Relative.	C	Relative.	Average for all treatments.	Relative.
Lowland permanent pasture.	1927 1928	45.83 31.14	100 68	43.23 30.23	100 69	38.10 26.56	100 69	42.37 29.64	100 69
Upland permanent pasture.	1927 1928	27.49 39.02	100 142	14.32 13.25	100 92	10.25 9.20	100 89	17.36 20.49	100 118

The figures given in Table X are based on the average of two lowland and two upland centres, and represent the data from the same plots cut each year.

The average results from the lowland centres here considered (July to October) show results in the same direction as those recorded from Nantcellan : the yield of 1928 (second year of drastic treatment) is of the order of 30 per cent. lower than that of 1927—twice as great as that we have computed to be due to weather differences. In the case of these centres the behaviour of the PKN plots has not been different from that of the PK and C plots. Thus permanent pastures of a type normally appertaining to the lowlands of Wales under a system of drastic defoliation appear to suffer from pre-treatment in a manner qualitatively similar to temporary leys. We have only one temporary ley from the trials under review yielding data which can be compared to the above results, and in this case the yield in 1928 (second year of drastic defoliation) on the PKN plots was 48 per cent. lower than in the first year of treatment—thus suggesting that temporary leys are decidedly more sensitive to drastic pre-treatment than are permanent pastures.

That drastic defoliation has a peculiarly marked influence on temporary leys is further suggested by comparing this reduction of 48 per cent. in the productivity from 1927 to 1928 with results from pure species plots similarly treated with PKN, which under monthly defoliation by sheep showed on the average of all the plots devoted to the various species and strains a reduction of but 25 per cent. from 1927 to 1928.*

The results from the upland centres are particularly interesting and in many respects entirely different from those given at the lowlands. We see that on the average for the PKN, PK and C plots 1928 has given 18 per cent. higher yield than 1927, while under PKN the advantage has been of the order of 40 per cent. with the plots subjected to two years consecutive drastic defoliation. If instead of the June to October period we consider the period June to the following spring, that is to say, if we include the winter growth, even the PK and control plots appear to show to the slight advantage of 1928 ; while the PKN plots would actually show an increase of 60 per cent. in favour of the second year of drastic defoliation. Taking these figures as a whole for the uplands and even granting that 1928 would seem to have been a more favourable growing year than 1927 for these centres (but only to the extent of about 6 per cent.), it is evident that the factors influencing the upland pastures have been quite different from those influencing the lowland pastures.

It has to be realized in the first place, that the upland pastures at the time of the commencement of the experiment consisted of a large amount of rough and dried herbage and much moss ; in the second place, that the soils were more deficient in plant foods than those of the lowlands, and that these upland swards had probably never previously received manures of any sort ; in the third place, that the upland swards were greatly lacking in leguminous herbs ; and in the fourth place, that the chief contributing species were the fine-leaved fescues and bent, while there was something in the nature of a " mat " associated with the sward. The flora then was one which appeared to be less sensitive to drastic defoliation than is the case when grasses like cocksfoot and perennial rye-grass are plentiful.†

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* This 25 per cent. is based on the yield of the pure species with the addition of wild white clover and weeds that had come into the plots—thus rendering the herbage more of the nature of a mixture. If only the pure species are taken into consideration the reduction was 38 per cent.—still well below 48 per cent.

† See, e.g. Jones and Jones (p. 38 of this bulletin).

The drastic defoliation completely removed all the rough and dried herbage and with the addition of PKN reduced the moss to almost negligible significance, while on the soils no doubt a second year of liberal manuring accounted for relatively much more than would have been the case on the lowlands, though probably as much as anything by its influence in further reducing moss and burned leafage, while the action of nitrogen as such was not here to any marked extent influenced by a great reduction in leguminous herbs (because the contribution of these herbs was initially but slight).

There can be but little doubt then that the treatment as a whole (PKN plus drastic defoliation) had caused a profound habitat alteration on these swards, an alteration which was probably greatly assisted by the human treading and firming consequent upon the conduct of the necessary defoliating operations.

The treatment in fact inspired the plants to take on a new and more vigorous habit of growth, which over a two-year period at all events was in no wise hampered by the effect of the drastic defoliation as such. The counterbalancing factors which were brought into play—whatever precisely their action, and which at present cannot be expressed in exact physiological terms—were the more important and the more fundamental in their immediate effect on the plant's inherent responsiveness to the radically altered conditions which the operation of such factors superimposed upon the habitat. The extent to which the habitat had in fact been altered—and this in the course of but two years—is brought home the more strikingly when it is stated that on the PKN plots the sum of weeds, moss and burned leafage had been reduced by as much as 37 per cent.

The Residual Effect of Manures under a System of Drastic Defoliation.

At one centre (Penglais, a good lowland pasture with fair excess of perennial rye-grass and white clover) the normal treatment in 1927 was followed in 1928 by again subjecting the plots to drastic monthly defoliation but without any further addition of manures.* A comparison is made between the yields of the two years in Table XI.

TABLE XI.—*To show the yield of eatables in cwt.* (=100 *lb.*) *of air-dry fodder per acre for plots cut with sheep shears on a monthly basis in* 1927 *and again in* 1928, *when manures were applied only in* 1927.

Year and treatment.	PKN.		PK.		C.	
	Yield.	Relative.	Yield.	Relative.	Yield.	Relative.
1927 with manures ..	76.47	100	58.11	100	54.89	100
1928 without manures ..	22.44	29	27.56	47	29.91	54

The difference in yield between the two years had been greater on this field than on other lowland centres considered, as is shown by the behaviour of the control plot. The point of interest is, however, the fact that by far the greatest

* This centre has not, of course, been included in the general averages discussed earlier in this paper, as the treatment was different in the two years.

reduction in yield in 1928 as compared to 1927 has shown itself on the plot treated with PKN during 1927. It would thus appear that the residual influence of the liberal manuring in 1927, far from assisting the plots to withstand a second season of drastic defoliation, has rendered them less capable of doing so. This piece of evidence, slender as it is taken by itself, is so important in its implications that it is worthy of notice, and it is the more worthy of notice because other trials now in progress, where tethered sheep are being used as the defoliating machines, have all the appearance of providing evidence of a similar nature. The effect of added nitrogen during a season of application is of course to enhance the vigour and productivity of the grasses : if, however, the herbage as produced is subjected to drastic defoliation one can conceive it as being highly probable that the plant's inherent vigour would be adversely affected by such a process, and that this would show itself in a second year, and the more markedly if nitrogen were withheld in such second year. The effect above noted could, however, also be explained in part at all events by the fact that the first year's application of nitrogen would have very greatly reduced the amount of wild white clover on the plot, and consequently in the second year most of the bulk would have to be provided by grasses. It is probable that a combination of the two effects has been responsible for the reduction in yield noted.

This evidence—if as evidence it is trustworthy, and considered in the light of all our experiments we think it is trustworthy—tends to show the fundamental importance of so regulating the degree of severity of grazing (that is to say, of defoliation) that no lasting harm shall be done to the sward. It is fairly evident, and indeed all the data discussed in this paper render it abundantly manifest, that the incremental application of a nitrogenous fertilizer does not safeguard the grazier against the bad effects of irrational grazing : it is far otherwise, and he can probably do much more harm both by *over-grazing* and by *under-grazing* a nitrogenized than a non-nitrogenized sward. The problem of how to use nitrogen to economic effect on grassland can only be solved when we know the degree of intensity of grazing required for each and all of the manifold types and conditions of pastures—temporary, permanent, lowland and upland—with which the farmer is concerned. The evidence brought under review in this paper has made at least one contribution to the solution of the problem : it has made it possible to show with regard to the ley as such, the lowland permanent pasture as such, and the upland permanent pasture as such, that each reacts in a very different manner to added nitrogen, at all events when the system of defoliation is drastic.

GENERAL CONCLUSIONS.

The most important practical conclusions which are to be drawn from the trials under discussion are :—

(1) Good temporary leys sown with indigenous species show a high yielding ability when compared with really good permanent pastures on relatively similar soil types.

(2) The all-the-year-round yields of upland pastures are poor compared with those of lowland pastures.

(3) Under drastic defoliation with sheep shears, incremental doses of nitrogen supplementing phosphatic and potassic dressings do not necessarily add to the yield of the best temporary leys.

(4) Nitrogen under such drastic defoliation greatly reduces the contribution made by wild white clover to the total eatables offering, and this reacts adversely on the mid-season yield of swards to which this clover is a heavy contributor.

(5) This fact points to the necessity of very carefully regulating the grazing on areas treated with added nitrogen so as to maintain a proper balance between grasses and clovers—the more so because, as is shown in the paper dealing with the chemical analyses, the clover content of the herbage has a marked influence on the nitrogen and lime content of such herbage.

(6) The upland pastures have responded relatively better than the lowland to PKN. This has been very largely due to a great reduction of moss, of burned and dried herbage and of weeds. It has also probably been due to the fact that the drastic cutting and human treading has to a large extent reduced the matted nature of these swards, and this is further suggested by the fact that in the second year of treatment at the uplands PKN has given a better result than in the first year, while in the lowlands the opposite was the case.

These trials have shown how very amenable upland swards are to treatment, and tend rather to suggest that the improvement of hill grazings may well be a comparatively easy and in many cases an entirely economic proposition.

The present results have been obtained from preliminary trials, which trials are now being supported by a more extensive series in which sheep and not sheep shears are being used as the defoliating machines; while further tests conducted on the "sheep shear" basis, but introducing additional schemes of manuring, were started in 1929.

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THE EFFECT OF MANURES ON THE NITROGEN AND MINERAL CONTENT OF UPLAND AND LOWLAND PASTURES.

BY

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The advance made in our knowledge of the food requirements of animals, and of the chemical composition of food stuffs has resulted in more and more attention being focused on the part played by minerals in animal nutrition.

It has long been known that particular ailments and malformation which live-stock in different parts of the Empire suffer from are due to deficiencies in certain essential mineral constituents of their diet (1).

The effect of these deficiencies is probably not as obvious in our own country as in some others, but there are indications that such deficiencies do exist, as, for example, rickets in pigs and foals, the licking of walls by young calves, and the gnawing of stones by cattle. It is therefore of great importance to know whether the foods fed contain the necessary supply of minerals.

On Welsh farms home-grown foods of which grass and hay form the major part enter largely into the diet of the live-stock, and investigations have shown that the mineral content of these varies considerably (2). Further, a comparison of the dry matter content of the herbage of lowland and hill grazing reveals the fact that the former is much richer in phosphoric acid and lime. Thus 100 lb. of lowland herbage would supply as much phosphate and lime as 165 lb. of hill grazing (3). When such differences as these are to be met with, it is not difficult to understand the well-known effect on the development of young growing stock following their transference from the hills to the lowland.

The soils of Mid-Wales tend to be poor in citric soluble phosphates, and are particularly poor in carbonate of lime, and the main system of farming followed, that is, the breeding of live stock, tends to further deplete the soil of these constituents. It naturally follows that unless these deficiencies are made up by the application of suitable manures, deterioration of the herbage and accentuation of the deficiencies in the soil will result. Previous investigations on the effect of the application of manures to pastures and hay fields have been carried out with two objects in view, increasing the yield and improving the botanical character of the herbage, and a great deal of valuable work has been done in these directions. It is, however, only recently that work has been conducted with the object of ascertaining the effect of different manures and mixtures of these on the mineral content of the herbage of pastures (1).

In the publications dealing with "manuring for mutton" at Newcastle and "manuring for milk" at the Midland Agricultural and Dairy College, it was shown that the application of suitable manures resulted in an increase in the stock carrying capacity of the pastures at both centres, and in an increase in the live weight at the former centre and in the volume of milk at the latter. It is more than probable that at both centres the enhanced nutritive value of the herbage was in no small measure due also to an improvement in its mineral content.

The application of phosphates to grassland generally increases the clover in the herbage, and as a result of this the protein and lime content of the produce are also increased. Nitrogenous manures increase the protein and usually decrease the fibre content of the herbage. Such facts as these are well-known, but our knowledge of the influence of individual manures and mixtures of these on the mineral content of home grown foods is neither extensive nor definite.

In the hope of adding to our information on this point, advantage was taken of an investigation carried out at the Station in seasons 1927 and 1928 into the effect of nitrogenous and other manures on the yield and botanical composition of the herbage of grassland cut monthly, to determine in addition their effect on the mineral content of the herbage.

The details as to the arrangement of the plots and the manuring have already been given on pages 3 and 4.

To illustrate the effect of the manures on the nitrogen, phosphoric acid and lime content of the herbage, two upland and two lowland centres have been chosen, and in Table I the mechanical and chemical analyses of the soil and subsoil at each of the selected centres are given.

TABLE I.—*Showing the mechanical and chemical analyses of the soil and subsoil of each centre.*

	Upland.				Lowland.			
	Llety. Centre 1.		Foel. Centre 2.		Rhoscellan. Centre 1.		Nantcellan. Centre 2.	
	Soil.	Sub-soil.	Soil.	Sub-soil.	Soil.	Sub-soil.	Soil.	Sub-soil.
Fine gravel	17.2	19.4	17.7	16.9	6.7	9.7	3.2	3.1
Coarse sand	8.8	7.6	8.1	6.7	3.9	6.6	2.8	3.9
Fine sand	4.9	5.3	17.9	12.4	17.5	16.2	13.6	11.8
Silt	16.7	18.2	13.5	18.6	10.2	14.7	15.4	20.0
Fine silt	18.3	17.8	16.7	19.4	36.7	34.2	34.9	32.2
Clay	10.7	11.4	8.6	12.9	9.0	7.2	15.1	18.0
Moisture	2.35	1.91	2.91	1.54	3.31	2.07	3.35	2.5
Loss on ignition	22.14	17.67	14.69	11.55	12.80	9.13	11.74	8.3
Nitrogen	0.59	—	0.38	—	0.34	—	0.30	—
P_2O_5 } soluble in 1 per	0.008	—	0.009	—	0.011	—	0.023	—
K_2O } cent. citric acid	0.024	—	0.013	—	0.02	—	0.019	—
P_2O_5 } soluble in HCl	0.11	—	0.12	—	0.13	—	0.24	—
K_2O } 48 hours digestion	0.61	—	0.56	—	0.57	—	0.63	—
Exchangeable CaO	0.043	—	0.051	—	0.089	—	0.41	—
pH	4.5	—	5.0	—	5.4	—	6.3	—

The soil of both upland centres is sedentary in character, while that of the two lowland centres is a heavy glacial drift. When the soils of the upland and lowland centres are compared, it is seen from Table I that they differ considerably both in mechanical and chemical composition, though the difference in mechanical composition between the two upland centres is small.

Taking the four centres, the percentage of available phosphoric acid varies from 0.008 to 0.023 per cent., the exchangeable lime from 0.043 to 0.41 and the

pH value from 4.5 to 6.3. All appear to be fairly well supplied with available potash, but it is only at one centre (lowland centre 2) that the soil contains a trace of lime in the form of carbonate of lime.

The soils, judged by their available phosphate and lime, appear to be particularly well suited to the purpose of the investigation, and when the mineral content of the herbage at both upland and lowland centres is examined it will be seen that there is considerable scope for improvement, especially in that of the upland centres.

The effect of the manures on the yield was much greater on the upland than on the lowland centres. Thus the average increase for the two seasons as a result of the application of phosphate and potash to the lowlands was 9 per cent. and 48 per cent. on the uplands. When nitrogen in addition was applied there was an increase of 33 per cent. in yield on the lowlands and 228 per cent. on the uplands.

The benefits pastures derive from the application of manures, however, are not to be estimated by the improvement in yield alone. Another important factor to be taken into consideration in such a valuation is the effect, if any, of the manures on the botanical character of the herbage, as this has an important bearing on the nutritive value of the produce.

The predominant species in the herbage of the four centres under discussion are shown in Table II.

TABLE II.—*Showing the predominant species in the herbage of two centres of the upland series and of two centres of the lowland series.*

Upland Series.		Lowland Series.	
Llety. Centre 1.	Foel. Centre 2.	Rhoscellan. Centre 1.	Nantcellan. Centre 2.
Fine-leaved fescues Bent Practically no clover	Bent Yorkshire fog A little clover	Bent Yorkshire fog Sweet vernal White clover Crested dogstail	Perennial rye-grass Cocksfoot Bent Some white clover Crested dogstail

The results obtained on the upland series of plots will be considered first: these are given in Table III. The figures have been abstracted from Tables VI and VII, in which the chemical composition of each monthly cut is shown.

Reference to Table II shows the predominant species in the herbage of Centre 1 to be fine-leaved fescue and bent, neither of which, when compared with other grasses under investigation at the Station, are outstanding in their phosphoric acid and lime content. Thus fine-leaved fescue occupies an intermediate position, while bent is decidedly low in lime and below the average in phosphoric acid content.

In Table III it will be noticed that clover is absent in the herbage of Centre 1, so that any effect the manure might have on the mineral content of the herbage may be ascribed to a direct rather than an indirect influence, such, for instance, as might take place if the clover content was increased. At this centre, the application of phosphates and potash has resulted in an increase in the nitrogen

TABLE III.—*Showing the average percentage of legumes in the produce of each upland plot for the two seasons, and the average percentage of nitrogen, phosphoric acid and lime in the dry matter of the herbage of these plots during the months June to September inclusive.*

	Season 1927.					
	Control.		Phosphate and potash.		Nitrogen, phosphate and potash.	
	Llety Centre 1.	Foel Centre 2.	Llety Centre 1.	Foel Centre 2.	Llety Centre 1.	Foel Centre 2.
Legumes	—	4.0	—	24.3	—	2.8
Nitrogen	2.08	2.76	2.41	3.00	2.84	3.18
Phosphoric acid	0.418	0.531	0.546	0.781	0.520	0.731
Lime	0.599	1.099	0.567	1.377	0.460	0.851
	Season 1928.					
Legumes	—	6.0	—	33.0	—	1.0
Nitrogen	2.31	2.64	2.60	3.65	3.39	3.31
Phosphoric acid	0.494	0.628	0.867	1.060	0.827	0.978
Lime	0.553	1.319	0.693	1.877	0.944	1.494

and phosphoric acid content of the herbage in both seasons, and although their effect on the lime content is negligible in the first season, it has resulted in an increase in this constituent in season 1928. The addition of nitrogen to the phosphatic and potassic manures has still further increased the nitrogen content of the herbage in both seasons, but has had a slightly depressing effect on the phosphoric acid. Its influence on the lime has been to depress it in the first season, but to increase it considerably in the second, when it will be remembered the nitrogenous manure was applied in the form of nitro-chalk (see page 4).

Table III shows that clover is present in Centre 2, and that the application of phosphates and potash has had a considerable effect on the percentage present in both seasons. When nitrogen in addition to phosphates and potash is applied, however, the clover is depressed to such an extent that the percentage is lower than that found in the control plot. The presence of clover in the herbage of Centre 2 masks to a large extent the direct effect of the manures on the herbage ; for it is impossible in the absence of data as to the contribution each plant makes to the total produce, and a knowledge of the chemical composition of each individual plant, to allocate the proportion of the increase in any of the constituents determined between the direct effect of the manures and the improvement they may have brought about in the type of herbage. A significant fact that bears on this point is that the only centre where clover is absent (Centre 1) is the one case in which the herbage shows an increase in lime as the result of the application of nitrogenous manure, and this only when the manure is applied in the form of nitro-chalk.

Table III shows clearly that the application of phosphates and potash increases the nitrogen, phosphoric acid and lime content of the herbage in both

seasons. When nitrogen in addition to phosphates and potash is applied, the nitrogen on the whole is increased, while the phosphoric acid in both seasons and the nitrogen in Centre 2 in the second season are depressed. The effect of the addition of nitrogen on the lime content of the herbage is to depress it in all except Centre 1, season 1928.

A comparison of the effect of the manures in the first and second seasons on the upland series of plots shows that of the phosphate and potash to be much more pronounced in the second than the first. Thus the nitrogen, phosphoric acid and lime content of the herbage as a result of the application of phosphate and potash is much higher in 1928 than 1927, and the same applies with regard to the produce of the plots receiving nitrogenous manure in addition to phosphates and potash. The important conclusions from a practical point of view to be drawn from this investigation are that by the application of manures to upland grazing the character of the herbage is improved, the yield of produce is much increased, and the mineral content of the herbage, which is exceedingly low in phosphoric acid and lime, may be greatly improved.

Taking next the results obtained on the lowland centres ; here the soil and herbage are naturally of a better type than those of the uplands, and in Table IV data similar to those already given for the uplands are shown : these have been abstracted from Tables VIII and IX.

TABLE IV.—*Showing the average percentage of legumes in the produce of each of the lowland series of plots for the two seasons, and the average percentage of nitrogen, phosphoric acid and lime in the dry matter of the herbage of the plots during the months May to September inclusive.*

	Control.		Phosphate and potash.		Nitrogen, phosphate and potash.	
	Rhoscellan Centre 1.	Nantcellan Centre 2.	Rhoscellan Centre 1.	Nantcellan Centre 2.	Rhoscellan Centre 1.	Nantcellan Centre 2.
Season 1927.						
Legumes	17.6	6.4	24.9	15.1	1.0	1.3
Nitrogen	2.90	2.96	3.17	2.98	2.85	2.96
Phosphoric acid	0.901	0.917	1.004	0.951	0.901	0.953
Lime	1.508	1.404	1.69	1.357	0.946	0.982
Season 1928.						
Legumes	21.5	3.5	21.5	8.5	1.0	1.0
Nitrogen	2.89	2.94	3.07	3.06	2.93	3.06
Phosphoric acid	0.895	0.811	0.996	0.980	0.891	0.932
Lime	1.435	1.431	1.529	1.746	1.239	1.365

From the above table, clover is seen to be present in the herbage of both lowland centres, and the effect of phosphates and potash upon it, though considerable, is not as great as it was on the clover content of the uplands. When, in addition to phosphates and potash, nitrogen is applied, its effect on the clover content, as was the case on the uplands, has been to reduce it to a lower level than on the control plots.

The effect of the manures on the nitrogen and mineral content of the herbage of the lowlands, though confirming in most particulars that obtained on the uplands, is not so striking. Thus in both seasons on the lowlands the application of phosphates and potash increases the percentage of nitrogen, phosphoric acid and lime, while the addition of nitrogenous manure with phosphates and potash appears if anything to depress the nitrogen and phosphoric acid and distinctly to depress the lime content of the herbage. The depressing effect of nitrogenous manure in the form of nitrate of soda on the phosphoric acid and lime content of the dry matter of herbage has been noted in previous work carried out at the Station (4).

Further, the second application of manures to the lowlands in 1928 has not affected the mineral content of the herbage to anything like the same extent as was the case on the uplands. This is probably accounted for by the fact that the lowland centres had previously received periodic applications of slag. The soil at the upland centres on the other hand was in such an impoverished condition that the dressing applied in the first year only partially removed its deficiency in esssential plant food constituents.

The usual practice in Wales is to transfer the younger sheep in the autumn from the uplands to the lowlands, allowing the breeding ewes and old wethers, if any, to remain on the hills. This being the custom, it is of interest to compare the composition of the herbage on the lowlands from October to April with that on the uplands during the same period.

In Table V are shown the average percentages of nitrogen, phosphoric acid and lime of the dry matter of the upland and lowland grazing from October to April and that of the upland grazing during the summer on the control plots.

TABLE V.—*Showing the average percentages of nitrogen, phosphoric acid and lime in the dry matter of the upland and lowland grazing from October to April, and that of the upland grazing during the summer on the control plots.*

Centres.	Period of year.	Nitrogen.	Phosphoric acid.	Lime.
Upland	October to April	2.10	0.454	0.717
Lowland	October to April	2.80	0.767	1.305
Upland	May to September ..	2.44	0.518	1.188

On comparing the nitrogen, phosphoric acid and lime content of the dry matter of the herbage on upland and lowland grazings from October to April, it is seen that the lowland grazing is superior in all three constituents. Further, the table shows the grazing on the lowlands to be superior even in winter (October to April) to that of the uplands in the summer (May to September).

When such differences as those shown in the above table in the nitrogen, phosphoric acid and lime content of the herbage of upland and lowland grazings are found, the general improvement in the appearance of young growing stock following their transference from the uplands to the lowlands is to a very large extent explained.

When comparing the effect of the manures on the mineral content of the

herbage of the upland and lowland centres, it has to be remembered that the soils of the upland centres show a marked deficiency in both citric soluble phosphates and exchangeable lime (Table I). Again, the herbage of the lowlands is superior to that of the uplands (Table II). Consequently, the manurial effect on the mineral content of the herbage would naturally be more pronounced on the uplands than on the lowlands.

As already pointed out, clover is present in the herbage of all centres with the exception of Centre 1 on the uplands, and the varying percentage of clover in the produce of any one series of plots cannot but influence the nitrogen and lime content of the herbage of those plots.

TABLE VI.

Upland (Llety) Centre 1.

Date of cutting.	Control.			Phosphate and potash.			Nitrogen, phosphate and potash.		
	Nitrogen. N.	Phosphoric acid. P_2O_5	Lime. CaO.	Nitrogen. N.	Phosphoric acid. P_2O_5	Lime. CaO.	Nitrogen. N.	Phosphoric acid. P_2O_5	Lime CaO.
Season 1927.									
1/ 7/27	2.03	0.396	0.630	2.11	0.376	0.518	2.55	0.376	0.434
1/ 8/27	2.23	0.460	0.616	2.45	0.626	0.623	2.97	0.578	0.525
1/ 9/27	2.20	0.456	0.581	2.80	0.618	0.602	2.81	0.566	0.476
1/10/27	2.11	0.444	0.518	2.45	0.622	0.580	3.07	0.574	0.476
1/11/27	1.86	0.336	0.651	2.27	0.490	0.511	2.81	0.508	0.392
Nov. to May	1.92	0.400	0.560	2.43	1.080	0.644	4.17	0.990	0.532
Season 1928.									
2/ 6/28	2.63	0.430	0.616	2.32	0.862	0.833	3.39	0.766	0.854
4/ 7/28	2.17	0.468	0.553	2.58	0.876	0.655	3.41	0.872	0.742
2/ 8/28	2.20	0.464	0.595	2.70	0.964	0.791	3.38	0.810	0.728
7/ 9/28	2.48	0.640	0.532	2.79	0.948	0.672	3.12	0.752	1.071
3/10/28	2.30	0.476	0.511	2.73	0.756	0.658	3.56	0.972	1.120
7/11/28	2.09	0.488	0.511	2.48	0.796	0.553	3.52	0.790	1.148
Nov. to May	1.79	0.354	0.385	2.24	0.651	0.469	2.47	0.532	1.190

TABLE VII.

Upland (Foel) Centre 2.

Date of cutting.	Control. Nitrogen. N.	Control. Phosphoric acid. P_2O_5	Control. Lime. CaO.	Phosphate and potash. Nitrogen. N.	Phosphate and potash. Phosphoric acid. P_2O_5	Phosphate and potash. Lime. CaO.	Nitrogen, phosphate and potash. Nitrogen. N.	Nitrogen, phosphate and potash. Phosphoric acid. P_2O_5	Nitrogen, phosphate and potash. Lime. CaO.
Season 1927.									
1/ 7/27	2.23	0.584	1.274	2.65	0.882	1.666	3.15	0.898	0.938
1/ 8/27	2.64	0.528	1.148	3.07	0.782	1.540	3.04	0.696	0.896
1/ 9/27	3.12	0.556	1.246	3.75	0.788	1.610	3.32	0.756	0.980
1/10/27	2.69	0.552	0.966	3.13	0.832	1.253	3.34	0.700	0.791
1/11/27	3.14	0.436	0.861	2.42	0.620	0.819	3.05	0.608	0.651
Nov. to May	2.58	0.522	1.064	3.01	1.216	1.624	3.84	1.128	1.323
Season 1928.									
2/ 6/28	2.37	0.596	1.090	3.15	1.018	2.044	2.89	0.906	1.127
4/ 7/28	2.52	0.712	1.386	3.63	1.158	2.002	2.72	1.054	1.323
1/ 8/28	2.62	0.640	1.344	3.71	1.052	2.023	2.93	0.944	1.337
7/ 9/28	2.88	0.640	1.379	3.73	1.016	1.848	3.17	0.998	1.701
3/10/28	2.72	0.596	1.330	3.82	1.188	1.736	3.50	1.022	1.869
7/11/28	2.72	0.582	1.387	3.87	0.918	1.610	4.68	0.946	1.610
Nov. to May	2.11	0.511	0.861	2.42	0.662	1.043	2.72	0.567	1.470

TABLE VIII.

Lowland (Rhoscellan) Centre I.

Season 1927.

Date of cutting.	Control. Nitrogen. N.	Control. Phosphoric acid. P_2O_5	Control. Lime. CaO.	Phosphate and potash. Nitrogen. N.	Phosphate and potash. Phosphoric acid. P_2O_5	Phosphate and potash. Lime CaO.	Nitrogen, phosphate and potash. Nitrogen. N.	Nitrogen, phosphate and potash. Phosphoric acid. P_2O_5	Nitrogen, phosphate and potash. Lime. CaO.
1/ 6/27	2.26	0.932	1.540	2.69	0.940	1.848	2.97	0.898	1.358
1/ 7/27	2.88	0.922	2.282	3.07	1.154	2.772	2.48	0.958	1.036
1/ 8/27	3.29	0.998	1.722	3.60	1.058	1.890	2.58	0.872	0.910
1/ 9/27	3.31	0.894	1.456	3.59	1.098	1.764	2.72	0.930	0.966
1/10/27	2.90	0.930	1.162	3.22	0.944	1.064	3.36	0.932	0.728
1/11/27	2.79	0.730	0.889	2.88	0.830	0.812	3.00	0.815	0.681
Nov. to May	2.56	0.810	1.253	2.97	0.890	1.085	2.92	1.014	1.106

Season 1928.

Date of cutting.	Control. Nitrogen. N.	Control. Phosphoric acid. P_2O_5	Control. Lime. CaO.	Phosphate and potash. Nitrogen. N.	Phosphate and potash. Phosphoric acid. P_2O_5	Phosphate and potash. Lime CaO.	Nitrogen, phosphate and potash. Nitrogen. N.	Nitrogen, phosphate and potash. Phosphoric acid. P_2O_5	Nitrogen, phosphate and potash. Lime. CaO.
31/ 5/28	2.23	0.752	1.316	2.30	0.838	1.120	2.27	0.788	1.183
3/ 7/28	3.15	0.838	1.505	3.24	0.908	1.680	2.46	0.804	1.148
31/ 7/28	3.18	0.880	1.792	3.32	0.938	1.988	2.63	0.844	1.274
31/ 8/28	3.16	0.940	1.526	3.51	1.164	1.792	3.99	0.948	1.344
28/ 9/28	2.84	1.564	1.463	3.18	1.136	1.533	3.22	1.040	1.239
5/11/28	2.79	0.896	1.008	2.91	0.992	1.064	3.03	0.922	1.246
Nov. to May	2.48	0.631	1.190	2.44	0.685	1.000	2.33	0.739	1.210

TABLE IX.

Lowland (Nantcellan) Centre 2.

Date of cutting.	Control.			Phosphate and potash.			Nitrogen, phosphate and potash.		
	Nitrogen. N.	Phosphoric acid. P_2O_5	Lime. CaO.	Nitrogen. N.	Phosphoric acid. P_2O_5	Lime. CaO.	Nitrogen. N.	Phosphoric acid. P_2O_5	Lime. CaO.
Season 1927.									
1/ 5/27	2.79	1.01	1.638	2.90	1.064	1.414	3.93	1.100	1.162
1/ 6/27	2.19	0.864	1.540	2.24	0.776	1.400	2.32	0.926	1.008
1/ 7/27	2.44	0.966	1.918	2.55	1.038	1.738	2.21	1.060	1.176
1/ 8/27	3.00	0.920	1.551	3.26	0.954	1.484	2.52	0.994	1.050
1/ 9/27	3.33	0.964	1.442	3.32	0.996	1.582	2.49	0.838	1.057
1/10/27	3.25	0.892	0.980	3.11	0.946	1.050	3.50	0.918	0.791
1/11/27	3.70	0.802	0.763	3.53	0.886	0.833	3.73	0.838	0.630
Nov. to March	3.67	0.960	1.435	3.72	1.400	1.554	4.73	1.398	1.316
Season 1928.									
30/ 4/28	2.97	0.780	1.183	3.47	0.868	1.967	3.48	0.970	1.491
31/ 5/28	2.25	0.822	1.372	2.57	1.030	1.708	3.04	0.808	1.366
3/ 7/28	2.41	0.752	1.400	2.77	0.912	1.750	2.56	0.828	1.078
31/ 7/28	2.90	0.722	1.652	2.37	0.974	1.911	2.66	0.862	1.435
31/ 8/28	3.04	0.806	1.565	3.05	1.018	1.834	2.83	0.928	1.470
28/ 9/28	3.51	0.876	1.477	3.67	1.048	1.582	3.36	1.014	1.414
5/11/28	3.53	0.918	1.372	3.50	1.012	1.470	3.50	1.120	1.302
Nov. to April	2.43	0.567	1.344	2.43	0.621	1.281	2.91	0.596	1.288

The fluctuations in the clover content of the herbage are, however, insufficient to account wholly for the variations in the nitrogen and lime content, and it is clear from Tables III and IV that there are other influences at work in determining the mineral content of the produce.

SUMMARY AND CONCLUSIONS.

(1) The application of phosphates and potash has resulted in an increase in the average percentage of nitrogen and phosphoric acid content of the herbage at all centres, both upland and lowland.

(2) Though no lime as such was applied to the plots, the addition of phosphates (superphosphate) and potash has resulted in an increase in the average percentage of lime in the herbage of the large majority of the plots.

(3) The effect of applying nitrogen in addition to phosphates and potash has been to depress the average percentage of phosphoric acid and lime and at the lowland centres if anything to depress even the nitrogen.

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THE EFFECT OF VARYING THE PERIODS OF REST IN ROTATIONAL GRAZING. (E. 93. SPRING FIELD).

BY

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Introduction.

During recent years there has been a change of opinion in regard to the proper management of pasture. Many farmers have increased the production of their grassland by adopting a system of high manuring in conjunction with rotational grazing of their fields. It is only in the last few years that the advantages of rotational grazing have been recognized, and the practice is still very restricted. As far back as 1839, however, Bishop (1) wrote "The fields . . . . " have been let to a respectable grazier for the last three years, on the under- " standing which he was ready to adopt, of shifting the stock from one field to " another at proper intervals and as frequently as possible, having one field " empty to allow a fresh spring of grass before the stock was again returned " upon it. This mode of grazing has been found so very beneficial, that instead " of different parties, who keep cows in the village of Methven, taking each " separate grass fields, they have all united and taken all the fields conjunctly, " in order to gain the advantages arising from the shifting of stock, and having " a regular supply of fresh pasturage for their milch cows throughout the " season."

Within the last few years it has been demonstrated by Fagan, Milton and Provan (2), and by Woodman *et al.* (6) that in young pasture grass the protein content is higher and the percentage of fibre lower than in older grass. Woodman has shown further that the digestibility of young grass is very high. Thus, when properly grazed, young pasture grass can to a large extent replace concentrated feeding stuffs used for high production both of milk and meat.

Experiments conducted by Stapledon (5) at the Welsh Plant Breeding Station to ascertain the relative productivity of plants under various frequencies of cutting have, however, shown that where the plants are cut back repeatedly they suffer in productivity. In a series of grass plots which were cut every week throughout the season the aggregate yield was found to be less than half that from a similar series of plots grown alongside but cut only once a month. When the number of cuts was reduced to two—hay and aftermath—the total bulk of dry matter was still higher, but owing to its fibrous nature and low protein content at this stage, the feeding value had been substantially lowered.

It is therefore evident that the frequency of grazing which, in practice, would give the maximum return in meat production lies somewhere between the large bulk with low feeding value and the small bulk with high feeding value. The present experiment was designed to ascertain the degree of frequency of grazing compatible with the highest animal production.

Material and Methods.

The experiment was carried out on the Spring field during 1928—29. The soil is a light loam formed from the Aberystwyth grits. The sward consisted of mixtures of grasses and clovers sown in June, 1927, and the grazing was so arranged that the sheep had equal access to all the mixtures under each scheme of grazing. The experiment was conducted during the first and second harvest years of the ley. The field received a dressing of 8 cwt. per acre of a high-grade slag. In 1928 three dressings of nitro-chalk, each at 1½ cwt. per acre, were applied, three similar dressings being again applied in 1929.

Three equal strips, each comprising 0.6 of an acre, were sub-divided into five plots, making a total of 15 plots. The grazing was arranged on a rotational basis so that on one strip the lambs were moved from plot to plot every week, thus giving each plot an interval of four weeks rest—this is referred to as the "month" strip. In the case of the next strip the lambs were moved from plot to plot twice a week, so that every plot had a fortnight's interval of rest between consecutive grazings—this is referred to as the "fortnight" strip. On the third strip—the "four-day" strip—the lambs were moved from plot to plot every day, so that each plot had only four days rest between the consecutive grazings. In each case water was supplied in small troughs on the plots.

Three sets of five lambs each were selected from the Station's flock of Kerry Hill sheep. On May 18th when the experimental grazing began these lambs had been weaned a fortnight, and varied from 12 to 16 weeks in age. The average weight of each lot was 58 lb. The lambs were subsequently weighed at weekly intervals, and precautions were taken to overcome the variation due to different degrees of fulness of stomach by weighing at the same hour of the day on each occasion. Weighing was done on the plots by means of a steelyard balance supported on a tripod, each lamb being suspended by a double body band.

It was found that this stocking was almost sufficient to consume practically all the fodder offering on the "four-day" strip, but on the "fortnight" and "month" strips a considerable amount of fodder remained after the scheduled period of grazing of each plot. To afford these plots the full rest period it was necessary to clear the extra fodder in a day. Additional sheep,

TABLE I.—*Showing the average increase in live weight per lamb in* 1928.

Resting period of sward.	Gain in lb. per week for the period			Total gain in lb. for period May 18 to Sept. 7.
	May 18 to June 12.	June 12 to July 31.	July 31 to Sept. 7.	
Month	2.83	1.59*	0.06*	22*
Fortnight	3.07	1.30	0.02	20
Four days	2.53	1.08	0.07	16
Average	2.81	1.32	0.01	—

* Owing to worm infection one lamb was excluded from this average.

sufficient in number to graze the plots bare in one day, were introduced to clear up each plot: they are referred to as "followers," and were for the most part two or three year old breeding ewes, each being reckoned to be equivalent in grazing to two lambs.

Discussion of Results: first harvest year.

The increments in live weight are shown in Table I, and for convenience have been divided into three periods. Generally speaking, it may be stated that the lambs made the most substantial increments at the beginning of the season. After some time they began to fall off in rate of increment, though they gained steadily until the end of July. During August there was practically no variation in live weight, but from observation and handling the opinion was formed that the lambs still continued to grow at the expense of condition. During the latter half of August scouring set in, with the result that there was a definite loss in weight. The scouring appeared first of all in the "four-day" lot, but eventually spread to the lambs on the fortnight old grass, and ultimately to those on the month old grass. Even at this stage all the lambs continued to grow in size.

The gain per lamb for the full period—May 18th to September 7th—shows that on the whole the lambs on the "month" strip did best, gaining 22 lb.; those on the "fortnight" strip gained 20 lb., whilst those on the "four-day" pasture gained only 16 lb. From the table it is seen that when this total gain is allocated to the different periods the "four-day" lambs made the lowest gain in each of the first two periods. The difference between the "month" and the "fortnight" lots is not so marked: at the beginning the "fortnight" lot made the most satisfactory increment, but by the second period the effect of the grazing had turned the balance in favour of the "month" lot. This was partly due to the fact that the drought affected the "fortnight" pasture to a greater extent than the "month" pasture, whilst the "four-day" strip appeared to suffer still more severely. During the last period there was no significant difference between the three lots in live weight increment.

Table II shows the number of lamb days which the strips carried of leaders and followers.

TABLE II.—*Showing the number of lamb days carried per acre in* 1928.

Resting period of sward.	Leaders.	Followers.	Total lamb days.
Month	933	624	1557
Fortnight	933	422	1355
Four days	933	292	1225

Thus it is seen that when the differences due to the method of management adopted in 1928 are compared, the most frequent grazing resulted not only in a less substantial increase in live weight but also in a lower carrying capacity, the totals per acre, from May 18th to September 7th, being as follows:—

Resting period of sward.	*Gain in lb. (live weight).*	*Lamb days.*
Month	183	1557
Fortnight	166	1355
Four days	133	1225

After September 7th the method of grazing on each strip was carried on with a batch of store lambs until December 7th. These, however, showed practically no gain or loss during the period, very little grass being produced.

THE EFFECT OF METHOD OF GRAZING IN 1928 ON THE SPRING GROWTH OF THE FOLLOWING YEAR.

The plots were rested from December 7th to May 7th, when a sample cut of the produce was taken from each strip—this representing the spring growth of 1929; see Table III (cf. also Fig. 1). It is seen that not only did the method of management during 1928 affect the output of each strip during that season, but it also made a distinct difference in the output during the spring of the following year. The plots less frequently grazed in 1928 gave 40 per cent. more growth in the following spring than the most frequently grazed strip. When the effect of management on the different species within the pasture is considered, the harmful effect of too frequent grazing is still more marked, the more productive grasses and clovers suffering very severely; the growth of cocksfoot, for example, on the "four-day" pasture was less than a third of that on the "month" pasture.

Fig. 1. Showing the relative spring growth in 1929 of grass (total bulk) under the three treatments, with the "monthly" rested pasture at 100.

The percentage contribution of the various species on May 7th (cf. Fig. 2, p. 44) shows that the weeds gave a higher percentage productivity on the short rest than on the long rest pasture, whilst species such as cocksfoot gave their highest percentage contribution on the long rest pasture.

TABLE III.—*Showing the effect of grazing in one year* (1928) *on pasture growth in the following spring up to May 7th.*

Resting period of sward.	Total produce (lb. per acre).	Yield of cocksfoot (lb. per acre).	Percentage productivity of cocksfoot.	Yield of white clover (lb. per acre).	Percentage productivity of white clover.	Yield of miscellaneous weeds (lb. per acre).	Percentage productivity of miscellaneous weeds.
Month	1458	513	35.2	39	2.7	58	4.0
Fortnight ..	1391	253	18.2	49	3.5	73	5.2
Four days ..	1047	149	14.2	20	1.9	59	5.6

This is the result of two opposing forces :—(*a*) Overgrazing—which by cutting the plant too frequently reduces its vitality : this has its maximum effect on the plants of high productivity, e.g. cocksfoot, and its minimum effect on the plants of low productivity, e.g. weeds. (*b*) Competition—under the long rest treatment the more vigorous plants tend to overshadow and check the slower growing plants.

Between the above two extremes were plants like wild white clover, which gave the highest percentage contribution under the " fortnight " rest treatment (cf. Fig. 2, p. 44). Analysis of pasture samples taken throughout the whole of the summer of 1929 also showed that wild white clover gives a higher percentage contribution on the fortnightly rested pasture—as the following figures indicate :—

Fodder on the monthly rested pasture contained 4.3 per cent. white clover.
,, ,, ,, fortnightly ,, ,, ,, 6.5 ,, ,, ,,
,, ,, ,, four-day ,, ,, ,, 4.1 ,, ,, ,,

Wild white clover, with its prostrate habit of growth, suffered from competition with the tall grasses under the monthly period of rest, and, on the other hand, suffered from excessive grazing under the " four-day " period of rest, but found its optimum under the " fortnight " rest period, which sufficiently reduced competition without unduly reducing the vitality of the plant.

Wild white clover, sown versus *unsown.*

When the spring productivity of wild white clover in plots where it has been sown is compared with that of plots where it has not been sown (see Fig. 3, p. 45) it is seen that under the " month " rest treatment the sown wild white clover gave four times as much growth. Under the " fortnight " treatment it gave only 40 per cent. more growth, while under the " four-day " rest treatment the productivity of sown and unsown white clover was reduced to a somewhat similar level.

This perhaps indicates that under a severe system of grazing on soils which are decidedly propense to the voluntary appearance of wild white clover there is very little gain in sowing this species, whereas under a more lenient treatment the gain is considerable.

Discussion of Results : second harvest year.

In order to ascertain the effects of the previous season's management on the pasture as measured by live weight increment all three strips were grazed alike for the first period from May 7th to June 14th. Eight lambs of an average weight of 50 lb. were used on each strip : grazing was conducted on a fortnightly rest basis. The average increments per week of the lambs for this first period are given in Table IV. These results show that though the strips were being treated alike in 1929, the strip rested for a month at a time during the previous year gave a substantially bigger increase in lamb weight. In addition to the greater gain in incremental weight of the leaders there was also more pasture left for the followers, thus showing the distinct benefit to early growth of the longer resting period practised during 1928.

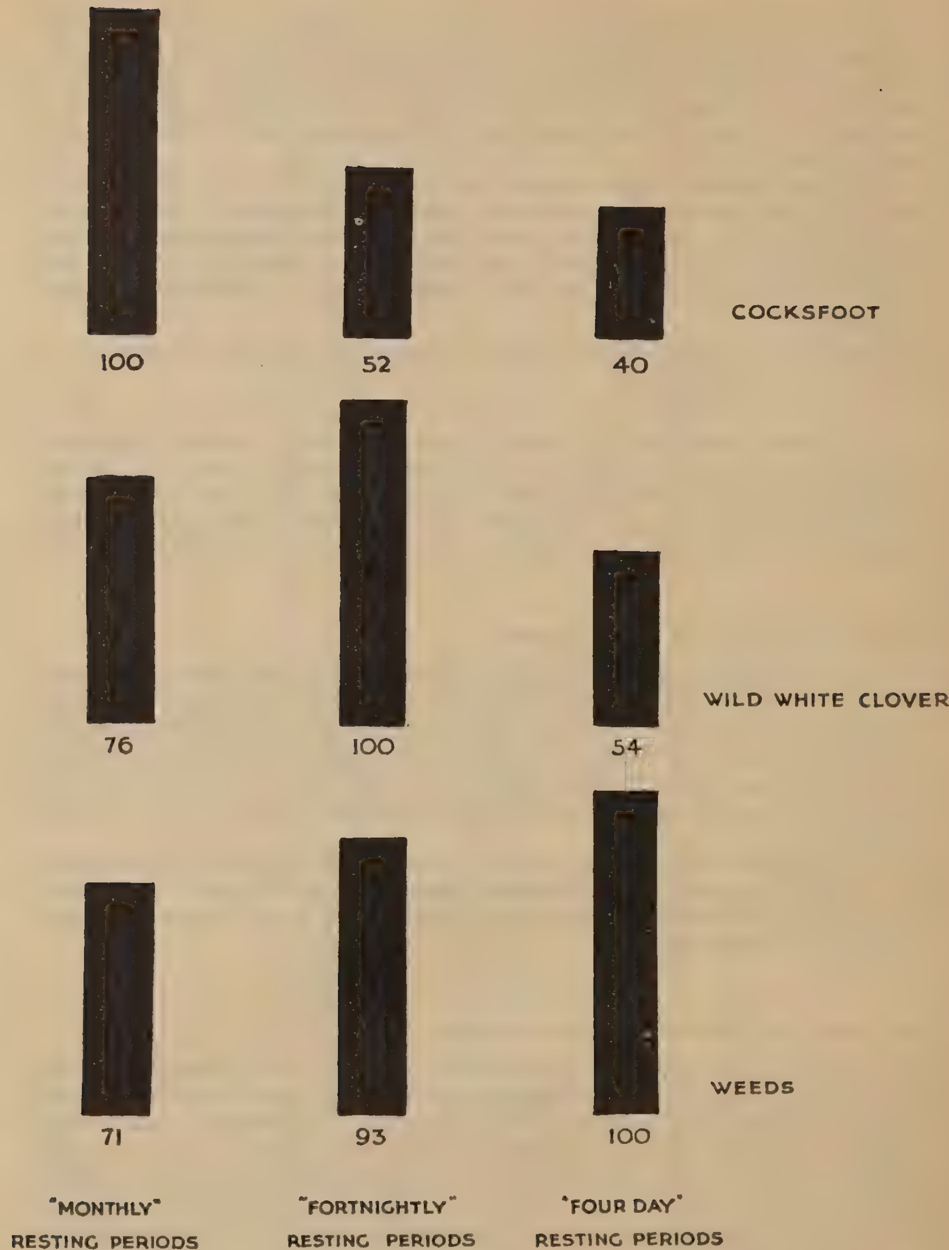

Fig. 2. Showing the relative spring contribution of cocksfoot, wild white clover and weeds under the three treatments, the highest percentage contribution in each case being placed at 100.

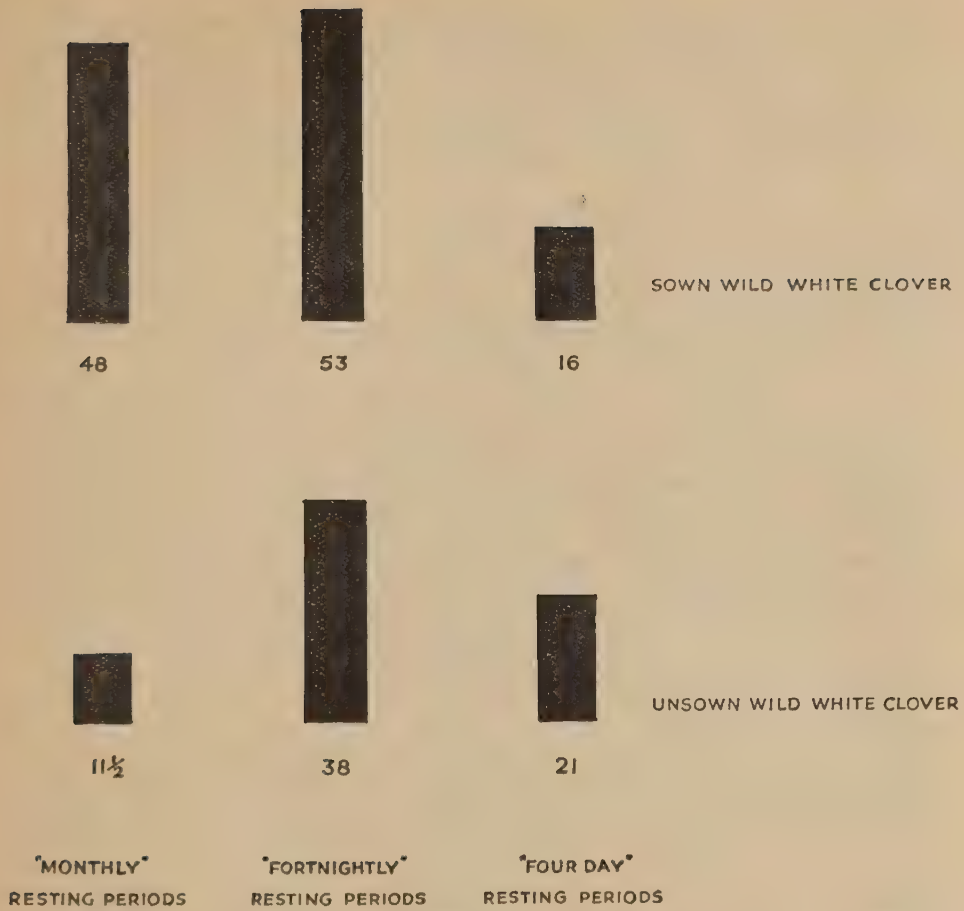

Fig. 3. Showing the relative contribution in lb. per acre under the three treatments of wild white clover when sown and when not sown.

On June 21st the method adopted in 1928 was reverted to, namely, resting periods of a month, a fortnight, and four days respectively. At this date also the lambs were re-grouped, their average weight being 57 lb.

The results for 1929 are shown in Tables IV and V. In spite of the fact that the number of lambs on each strip was reduced from 8 to 7 during the last period of grazing—July 31st to September 7th—the rate of increase was very low, indicating that as in 1928 there was a distinct falling off in the rate of increase as the season advanced. It should be mentioned that the " month " strip gave a distinct increase up to August 9th, at which date, however, the lambs began to scour, whilst those on the " four-day " and " fortnight " strips did not suffer. This was in contrast to their behaviour in 1928, when scouring occurred first among the short grass lambs. It would appear that the method of grazing on the monthly rested pasture was the cause of scouring in 1929.

TABLE IV.—*Showing the average increase in live weight per lamb in 1929.*

Resting period of sward.	Gain in lb. per week for the period			Total gain in lb. for period May 7 to Sept. 14.
	May 7 to June 14.	June 21 to July 25.	July 25 to Sept. 14.	
Month	1.39*	0.76	0.28	13.4
Fortnight	1.13	0.86	0.39	13.3
Four days	1.13*	0.26	0.38	10.2

* For the first grazing the resting period of all traverses was a fortnight.

At the end of each week's grazing the ration of the lambs on the "month" strip was rather short and stemmy and somewhat soiled, while following removal to a new plot a fresh growth of luscious grass consisting predominantly of leaf was available. This change of diet caused overfeeding, which manifested itself in scouring. In order to verify this point a new group of lambs was placed on the plots on September 14th and the method of grazing on the "month" strip was so modified by a system of hurdling off sub-folds that the lambs had access to a small area of fresh grass on alternate days. In this case no scouring occurred.

In spite of scouring, the total live weight increment on the "month" pasture was equal to that on the "fortnight" pasture, and more than 30 per cent. higher than that on the "four-day" pasture (see Table IV).

Table V shows the number of lamb days obtained in 1929 from each strip for leaders and followers.

TABLE V.—*Showing the number of lamb days carried per acre in 1929.*

Resting period of sward.	Leaders.	Followers.	Total lamb days.
Month	1568	297	1865
Fortnight	1568	132	1700
Four days	1568	127	1695

The results obtained in 1929 may be summarized as follows :—

Resting period of sward.	*Gain in lb. (live weight) per acre.*	*Lamb days per acre.*
Month	175	1865
Fortnight	167	1700
Four days	132	1695

These results confirm the findings of 1928—that when the pasture is rested for only four days at a time it gives a much smaller increment in live weight and also a reduced stock-carrying capacity as compared with fortnightly rested pasture, and still more so as compared with monthly rested pasture.

Chemical composition of the pasture.

Samples of the pasture were taken from each strip at intervals during 1928 and chemically analysed ; the results are presented in Tables VI and VII.

It is seen from Table VI that there was very little difference between the various strips with regard to the chemical composition of their fodder. The monthly rested pasture, however, was slightly higher in fibre, but lower in protein, phosphate and lime.

The chemical composition of the pasture at different periods of the year, on the other hand, shows a wide variation (see Table VII). The late period—July 31st to September 7th—is characterized by a much lower percentage of carbohydrates but a higher percentage of fibre, protein, phosphate and lime as compared with the first period—May 18th to June 12th. With the exception of fibre content, which was at its highest in June and July, all the remaining constituents were intermediate in value during the second period.

The relation of chemical composition of the pasture to live weight increment.

When the live weight increment made on the respective strips is compared with the chemical composition of the pasture on those strips, it is seen that the highest live weight increment was obtained from the strip having the lowest percentage of protein, phosphate and lime—this was the monthly rested strip.

Comparing the live weight increment obtained at different periods of the year, the highest increment was obtained when the pasture was again lowest in protein, phosphate and lime, but highest in soluble carbohydrates (see Fig. 4, p. 50).

Indeed the rate of fattening was so rapid in the early stages and fell away so markedly as the season advanced that it seems highly probable that the different constituents were nearest their optimum ratio during the first period, whereas later on they became unsuitable, either in their nature or in the proportion in which they occurred. During the last period the scouring would usually be regarded as an indication of excess of protein, but the tendency to grow at the expense of fattening might in this case be correlated with the high lime and phosphate content coupled with the high protein content.

Common experience in the feeding of cattle would seem to support this supposition, for in the finishing stage cotton cake, which is high in protein and low in lime, is frequently used when the animals are grass fed.

During recent years it has been found more economical to feed cakes rich in carbohydrates rather than those containing a high percentage of protein. Yet the high protein content of the old method did not seem to have any ill effects, whereas it would almost appear from the results of these experiments that grass which is high in both protein and lime content tends to make the animals grow rather than fatten.

Other factors influencing rate of live weight increment.

In addition to the chemical composition of the pasture the live weight increment of sheep depends on the following factors :—

(*a*) age of lambs,

(*b*) degree of fatness, and

(*c*) accessibility of food.

TABLE VI.—*Showing the percentage chemical composition of pasture with different intervals of rest.*

Resting period of sward.	Soluble carbo-hydrates.	Crude fibre.	Crude protein.	True protein.	Ether extract.	Silica-free ash.	Phos-phoric acid. P_2O_5.	Lime CaO.	Ratio of non-nitrogenous crude nutrients to nitrogenous crude nutrients.
Month ..	42.5	29.8	15.3	12.5	3.09	7.72	0.654	1.23	4.9
Fortnight ..	43.5	28.2	15.8	13.4	2.96	7.45	0.727	1.31	4.7
Four days ..	43.4	27.7	16.3	13.6	2.94	7.06	0.723	1.29	4.5

TABLE VII.—*Showing the percentage chemical composition of pasture at different periods of the year.*

Period.	Soluble carbo-hydrates.	Crude fibre.	Crude protein.	True protein.	Ether extract.	Silica-free-ash.	Phos-phoric acid P_2O_5.	Lime CaO.	Ratio of non-nitrogenous crude nutrients to nitrogenous crude nutrients
May 18th—June 12th	50.5	25.8	13.0	9.7	3.48	5.97	0.59	1.02	6.14
June 12th—July 31st	42.9	30.3	15.2	13.0	2.62	7.02	0.66	1.21	5.05
July 31st—Sept. 7th	39.0	28.0	18.5	15.7	3.20	8.82	0.82	1.46	3.80

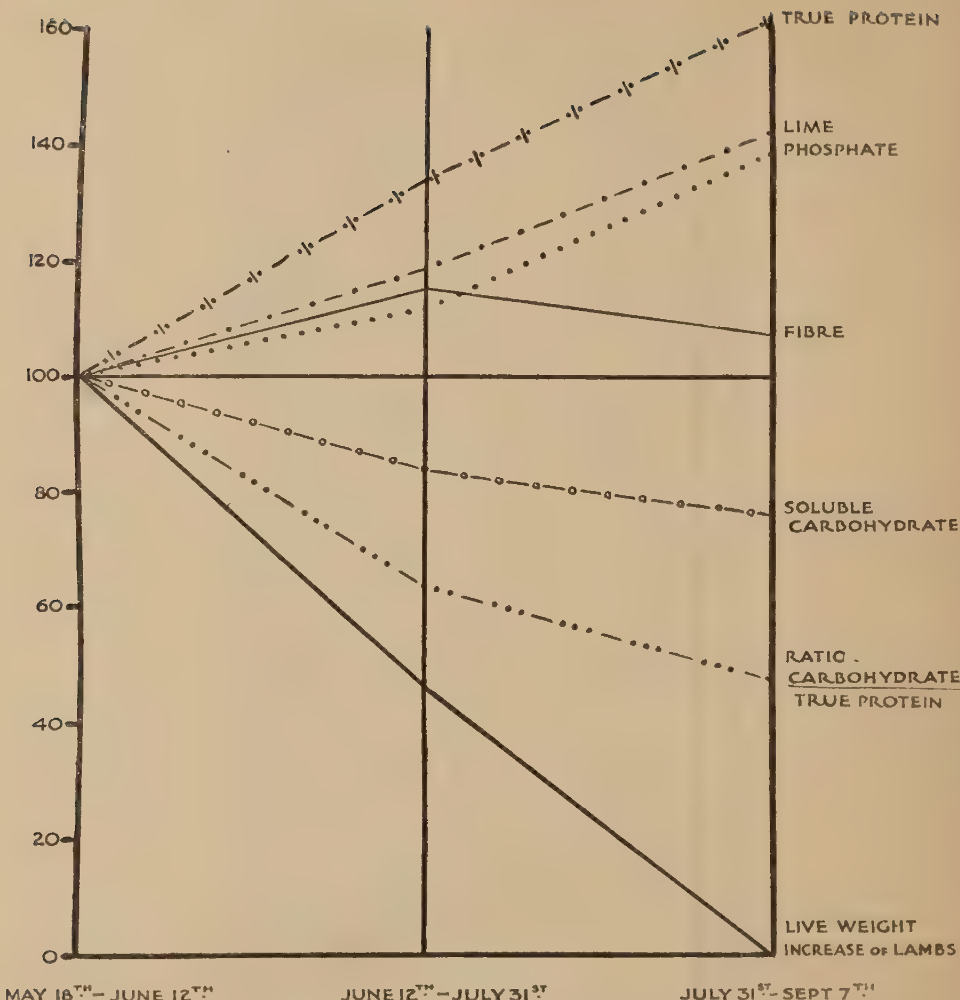

Fig. 4. Showing the trend of variation in chemical composition and live weight increase with advance of season in 1928 (the values for the period May 18th—June 12th placed at 100).

Phillips (4) has shown that in ordinary fat lamb production, lambs born in spring fall away very rapidly in daily gain from May to August, when they come to a standstill.

Though it is not possible to set up a definite standard by which to measure the degree of fatness, yet it is common knowledge that all animals increase at a slower rate towards the end of their fattening period if the food remains the same. In actual practice, therefore, it is usual to give a more concentrated ration during the final stages of fattening.

During June and July, 1928, the sheep were kept under observation on six occasions from 9-0 a.m. till 5-0 p.m. ; the time taken for grazing, chewing the cud and resting was noted for each sheep on the three traverses. The " sheep watch " dates were June 22nd, 25th and 28th, and July 2nd, 6th and 17th. On these days samples of the pasture were taken in order to determine the amount of food offering.

TABLE VIII.—*Showing the relative amount of food offering and the behaviour of the sheep on the pastures under three types of management, the " monthly " rested pasture being placed at* 100.

	Monthly rested pasture.	Fortnightly rested pasture.	Four-day rested pasture.
Grazing	100	114	119
Chewing	100	78	67
Resting	100	74	72
Food offering	100	50	47

The results are shown in Table VIII, the values obtained from the monthly rested pasture being placed at 100 and the other values calculated accordingly.

It is seen that the fodder was far more abundant on the monthly rested pasture and that the sheep spent less time in acquiring their food, i.e. in grazing, than they did on the other two pastures where the grass was never long enough for them to obtain a really good bite. Further, the extra amount of time taken to chew the grass (on the monthly rested pasture) indicates that the sheep actually ate more in this shorter period of grazing and also had more time to rest.

The sheep which show the most substantial increases in this experiment are those that spent the least amount of time grazing, and thus had more time at their disposal for resting.

It has been shown earlier in this paper (see Table I, p. 39) that the sheep on the monthly rested pasture gained more in weight than those on the other two pastures during this period. Thus it would appear that the greater increase in weight of the sheep on the monthly rested pasture depends partly on the availability of the food, which in turn regulates the amount of time and energy spent in obtaining this food and also the amount of time available for resting, which confirms previous work (3).

The effect on the botanical composition of the pasture of varying the length of the resting period.

The pasture was analysed in March, 1930 : turves 6 in. by 6 in. were lifted from each strip and the number of tillers of each species was counted.

Table IX shows the percentage contribution of tillers of each species to the pasture. It is seen that bent is the species of most frequent occurrence under every system of management, but its contribution increases considerably on the

"short rest period" pasture. Then follow rough-stalked meadow grass, perennial rye-grass and crested dogstail, but, unlike bent, their percentage contribution to the pasture decreases with the shorter resting period. Yorkshire fog, cocksfoot, annual meadow grass, fine-leaved fescue, sweet vernal, miscellaneous weeds and white clover are present in descending order; together with small amounts of Italian rye-grass, timothy and red clover.

TABLE IX.—*Showing the effect of the three types of management on the botanical composition of the pasture, expressed as percentage tillers of each species.*

Species.	Monthly rested pasture.	Fortnightly rested pasture.	Four-day rested pasture.
Bent	29.6	29.0	42.0
*Rough-stalked meadow grass	16.3	16.3	10.8
*Perennial rye-grass	12.0	13.0	12.2
*Crested dogstail	11.3	11.5	9.6
Yorkshire fog	8.7	6.5	6.8
*Cocksfoot	6.7	3.8	2.6
Annual meadow grass	4.7	8.2	3.2
Fine-leaved fescue	3.2	3.9	4.0
Sweet vernal	2.9	1.8	2.8
*Timothy	0.2	Trace	Trace
*Italian rye-grass	0.1	Trace	Trace
*White clover	1.8	2.0	1.8
*Red Clover	Trace	Trace	Trace
Miscellaneous weeds	2.6	4.0	4.2
Average sown species	48.4	46.6	37.0
,, unsown species	51.6	53.4	63.0
Average number of tillers per 6 in. X 6 in. area	345	363	412
Moss	12.7	11.3	14.5

* Sown species.

The most significant fact brought out by the analysis, however, is that the species which were sown in the original mixture contribute far less under the short resting period than under the monthly resting period. On referring to Table IX it is seen that the sown species constitute 48 per cent. of the tillers on the monthly rested pasture as compared with only 37 per cent. on the four-day rested pasture; the remaining tillers formed by the unsown species constitute only 52 per cent. on the monthly rested pasture, whereas under the short resting period they increase to 63 per cent. Further, the number of tillers per unit of area increases with the reduction in duration of the resting period. This is probably due to a decrease in size of the tillers following constant defoliation by grazing, and thus it is possible to obtain a greater number of these small tillers per unit of area than of the larger tillers under less constant defoliation. The increase in bent, which has naturally smaller tillers than the sown species, also affects the result considerably.

TABLE X.—*Showing the effect of the length of the resting period on the tiller production of individual species, the value of the monthly rested pasture being placed at* 100 *for each species. E.* 93. *Spring Field.*

Species.	Monthly rested pasture.	Fortnightly rested pasture.	Four-day rested pasture.
Red clover	100	100	11
Timothy	100	20	27
Cocksfoot	100	60	47
Italian rye-grass	100	60	55
Rough-stalked meadow grass	100	105	79
Annual meadow grass	100	183	82
Yorkshire fog	100	79	92
Crested dogstail	100	108	102
White clover	100	111	116
*Perennial rye-grass	100	114	122
Sweet vernal	100	88	135
Fine-leaved fescue	100	128	148
Bent	100	102	168
Miscellaneous weeds	100	161	191

* These figures are hardly comparable for perennial rye-grass, because one-third of the rye-grass turves on the monthly rested pasture are situated on poor soil and these have considerably lowered the total tiller production under the monthly rested system.

In this analysis the amount of moss on each turf was estimated on a 0—10 scale of marks : the numbers in the table are therefore only relative, but they show that constant defoliation and close grazing tend to induce the growth of moss in a pasture.

Table X shows that the various species of plants respond differently to the three systems of management. Comparing the monthly rested pasture with the four-day rested pasture it is seen that in the former the number of tillers of the first four species is more than twice that in the latter : in the case of the

TABLE XI.—*Showing the effect of management on the tiller production of sown species and on that of unsown species, the monthly rested pasture being placed at* 100 *in each case.*

	Monthly rested pasture.	Fortnightly rested pasture.	Four-day rested pasture.
*Sown species	100	78	72
†Unsown species ..	100	112	145

* Sown species include perennial rye-grass, Italian rye-grass, cocksfoot, timothy, crested dogstail, rough-stalked meadow grass.

† Unsown species include fescue, bent, Yorkshire fog, sweet vernal, miscellaneous weeds. Annual meadow grass was excluded on account of its being an annual.

Wild white clover, though sown in several of the mixtures, is not included in the sown species owing to its being so highly indigenous to the field.

last three species included in the table a considerably larger number of tillers is produced under the four-day resting period system of management.

Between these two extremes are found grasses which are not so sensitive to management, but most of which show a distinct upward or downward trend in the production of tillers according to the length of the resting period. Annual meadow grass is noteworthy in that it produces a very large number of tillers on the fortnightly rested pasture. This is probably explained by the fact that it is an annual which depends on seed production for its continuity in a pasture. Under the short rest system the sheep continually nibble the young inflorescences and thus inhibit seed production : under the monthly rest system it is hampered owing to the good growth made by the other species.

The effect of management on tiller production of the sown grasses as compared with its effect on unsown species is shown by Table XI. It is evident that the better type of grasses suffer more from too short a resting period and thus afford the less productive weed species a much better opportunity to spread and colonise the ground, whereas under the monthly rest system the better and quicker growing grasses are able to keep the weed species well in check.

TABLE XII.—*Showing the differential effect of management on tiller production in different strains of the same species—commercial and indigenous cocksfoot—the values of the monthly rested pasture being placed at* 100.

	Monthly rested pasture.	Fortnightly rested pasture.	Four-day rested pasture.
Commercial cocksfoot ..	100	23	14
Indigenous cocksfoot ..	100	85	70

From Table XII it is seen how two strains of the same species—cocksfoot—react to the management of a pasture. Though the number of tillers is reduced in both the indigenous and commercial strains under the short rest management, the effect on commercial cocksfoot is much more pronounced than on indigenous cocksfoot. Commercial cocksfoot is a hay type of rather short duration, while indigenous cocksfoot is a leafy, persistent plant much more suitable for grazing.

This variation between a hay type and a pasture type within the same species is further borne out by the variation between typical hay and pasture species, as shown in Table XIII, where the grasses have been grouped into hay and pasture grasses—Italian rye-grass, timothy and commercial cocksfoot being placed in the hay group, and rough-stalked meadow grass, crested dogstail and indigenous cocksfoot being placed in the pasture group. These results indicate that the rapid growing hay producing grasses suffer far more from too short a period of rest for recuperating than pasture types which, owing to their greater leafiness and prostrate habit of growth, are not so liable to have their delicate growing parts nibbled off by the sheep.

Table XIV shows how tiller production of certain species is differently affected under various types of management when they are sown with two

TABLE XIII.—*Comparative results for hay and pasture grasses under the three types of management.*

	Monthly rested pasture.	Fortnightly rested pasture.	Four-day rested pasture.
Hay types.			
Cocksfoot (commercial), Italian rye-grass and timothy	100	34	32
Pasture types.			
Cocksfoot (indigenous), crested dogstail and rough-stalked meadow grass	100	99	84

different main grasses. Five mixtures in the above experiment were sown with perennial rye-grass but no cocksfoot, while five other plots were sown with cocksfoot without rye-grass. In the Table the number of tillers of various species when sown with perennial rye-grass in the three types of management is compared with that when the same species were sown with cocksfoot. Taking the average for these species and placing the monthly rested pasture for perennial

TABLE XIV.—*Tiller count results for various species under the three systems of treatment when sown with perennial rye-grass and when sown with cocksfoot: monthly rested pasture being placed at* 100.

Species.	Monthly rested pasture.	Fortnightly rested pasture.		Four-day rested pasture.	
		Perennial rye-grass series.	Cocksfoot series.	Perennial rye-grass series.	Cocksfoot series.
Perennial rye-grass ..	100	97	—	109	—
Cocksfoot	100	—	69	—	55
Crested dogstail	100	94	154	87	117
Rough-stalked meadow grass	100	77	94	54	75
Fescue	100	157	170	231	183
Bent	100	113	131	156	212
Yorkshire fog	100	33	81	48	119
Sweet vernal	100	108	60	115	138
Annual meadow grass ..	100	131	195	37	106
Wild white clover ..	100	98	117	73	159
Weeds	100	193	169	200	191
Bare ground	100	90	86	99	79
Moss	100	110	82	135	98
Average	100	111	130	111	144

rye-grass and cocksfoot each at 100, the tiller population with perennial rye-grass on the fortnightly rested pasture has increased by 11 per cent., whilst that with cocksfoot as the main grass has increased by 30 per cent. Further, under the short period rest (four days) the number of tillers of other species is 111 under perennial rye-grass, whilst under cocksfoot it has reached 144.

This can be explained by studying the effect of management on the two main species, perennial rye-grass and cocksfoot. In the case of the latter, grazing reduced the number of tillers to 47 per cent., and thus the area which previously carried cocksfoot (53 per cent.) was rapidly colonised by weed grasses. On the other hand, the number of perennial rye-grass tillers increased with the shorter resting period, and other species were thus afforded less opportunity for encroachment. This Table also brings out an interesting point in regard to the moss content of the pasture. In the perennial rye-grass pasture the amount of moss increased from 100 on the monthly rested pasture to 135 on the four-day rested pasture. In the cocksfoot pasture the amount of moss is lower on the four-day rested and fortnightly rested pastures than on the monthly rested pasture. It is also found that the cocksfoot plots are much more mossy than the perennial rye-grass plots on the monthly rested pasture, and previous observations have also indicated that cocksfoot plots tend to be more mossy than perennial rye-grass plots.

TABLE XV.—*Showing the effect of management on the weed content of a pasture expressed as percentages of the weeds on the four-day rested pasture. E.* 93. *Spring Field.*

Species.	Monthly rested pasture.	Fortnightly rested pasture.	Four-day rested pasture.
Field woodrush	7	54	100
Yarrow	30	40	100
Veronica	38	122	100
Pearlwort	42	73	100
Chickweed	45	81	100
Self-heal	46	77	100
Sheep's sorrel	48	56	100
Cat's ear	55	139	100
Buttercup	76	78	100
Daisy	140	149	100
Other species	49	112	100
Average	52	89	100

In the case of perennial rye-grass plots the continuous close grazing of the four-day rested pasture induces a good growth of moss : in the cocksfoot plots the reduction in the amount of cocksfoot on the short rest period pasture tends towards a reduction of moss, whilst the management in itself tends to increase it, with the result that there is little change in one direction or the other.

Table XV shows the effect of management on the individual weed species of a pasture. It is remarkable that with the exception of only one species—daisy—fewer weed tillers were found on the monthly rested pasture than on the four-day rested pasture, whilst without exception there were more tillers of every

weed species on the fortnightly rested pasture than on the monthly rested pasture. From this table it seems as if woodrush benefits more from close grazing than any weed species, whilst on the monthly rested pasture it practically disappears.

It seems very probable, therefore, that one of the best methods to reduce the weed content of a pasture is to adopt a rotational grazing system with a fairly long resting period—about a month.

SUMMARY.

The effect of varying the periods of rest in the rotational grazing of a pasture has been investigated in relation to a temporary ley in its first and second harvest year. It was found that pastures receiving a month's rest between successive grazings gave a higher live weight increase and also carried more sheep per acre than pastures receiving four days rest between successive grazings.

The fortnightly rested pasture was intermediate in production between the monthly and the four-day rested pastures, approximating to the former in regard to the increase in live weight produced and to the latter in regard to carrying capacity.

Though previous chemical analyses have shown that the younger the grass the richer it is in protein, and the more digestible are its nutrients, yet this experiment has demonstrated that grass a month old from a temporary ley is still sufficiently rich in digestible nutrients to fatten young stock—lambs 3 to 6 months old.

The rate of live weight increment fell off in both years as the season advanced: this was correlated with a reduction in carbohydrates and an increase in protein, phosphate and lime content of the pastures.

The experiment has also shown the importance in the management of animals of rendering available each day food of a uniform quality, in order to obviate digestive disturbance. Tethering of the animals ensures that fresh pasture is grazed each day, or, if desired, even twice a day. Again, the animals may be turned on to an adjacent and fresh plot for one or two hours each day and be put back upon the original soiled plot for the remainder of the time. The latter is probably the more practical method. A comparison of the behaviour of sheep on the three pastures was made, and this showed that on the monthly rested pasture the food was more accessible—hence the sheep spent less time grazing and more time resting, and this in itself is conducive to better growth and fattening of the animals.

It was further demonstrated that the management of the ley in one year had a marked effect on its growth in the following spring, and that the longer the resting period between successive grazings in one year the more vigorous is the growth of the pasture in the following spring. Further analyses showed that management had its maximum effect on the species of high productivity, whilst the species of low productivity suffered little, or may even have benefited by the system of the short rest period with the consecutive close grazing.

Pasture analyses of the sward showed that management has a considerable effect on botanical composition, and that under the four-day resting period of the pasture, or what practically amounts to constant grazing, the number of tillers of :—

(*a*) certain species, e.g. cocksfoot, Italian rye-grass and timothy, was greatly reduced :

(*b*) other species, e.g. bent, fine-leaved fescue and miscellaneous weeds, was increased considerably :

(*c*) sown species was, on the whole, reduced :

(*d*) unsown species was increased :

(*e*) commercial cocksfoot was reduced far more than that of indigenous cocksfoot :

(*f*) hay types of grasses was reduced to a much greater extent than that of the pasture types of grasses :

(*g*) all miscellaneous weeds species, with the exception of daisy, was greatly increased,

as compared with the number of tillers in the monthly rested pasture.

Further, it was shown that the total number of tillers per unit of area was increased, due chiefly to the increase of unsown species ; and also that the moss content of the pasture was greater on the four-day rested pasture than on the monthly rested pasture.

It was also found that certain species react differently or to a different degree when sown with a high seeding of perennial rye-grass and when sown with a high seeding of cocksfoot under the different systems of management. This is due to cocksfoot being so susceptible to continuous grazing : it thus affords other species better opportunities for growth, whereas perennial rye-grass increases, and under a system of continuous grazing does not allow the other species to make such headway.

The experiment is being continued on the same plots for a further period of years.

Acknowledgments.

Grateful thanks are due to Mr. T. W. Fagan, M.A., F.I.C., for advice and help in connection with the chemical aspects of this work.

We are also indebted to Mr. T. W. Evans, B.Sc., who, under Mr. Fagan's supervision, kindly conducted the analyses which have provided the data from which Tables VI and VII have been prepared.

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SOME OF THE FACTORS INFLUENCING YIELD AND QUALITY OF RED CLOVER SEEDS.

BY

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Introduction.

During the eight years 1921—1928 a number of experiments have been conducted at the Welsh Plant Breeding Station with a view to investigating some of the factors influencing yield and quality of red clover seed. In this paper an attempt has been made to collate the results of these investigations. A number of the experiments were undertaken primarily with the avowed object of procuring more information than is at present available concerning the best way of dealing with breeding material, and consequently some of the results will be of direct interest only to the plant breeder. However, the results of most of the investigations have a direct practical bearing, inasmuch as they throw a certain amount of light on some of the difficulties connected with red clover seed production.

Some of the ground covered in this paper has already been studied by other workers. Reference to these investigations will be made in the body of the report.

Although the writer has already in his possession a considerable amount of data concerning the modes of inheritance of some of the factors influencing the yield and quality of seed, more particularly on cross-sterility and seed colour, it is not proposed in this paper to deal with the genetical aspect of the problem ; this is reserved as the subject of a future paper.

It appears from the results of the investigations conducted by Fergus (1922) and Kirk (1925) that red clover is appreciably more self-fertile in the United States and Canada than in Britain. In this country the crop may be regarded for all practical purposes as completely self-sterile ; cross-pollination is mainly effected through the agency of a comparatively small number of species of humble bees, assisted to a very slight extent in dry summers by honey bees.

Most of the data considered in this paper were obtained on populations of single spaced plants growing under normal field conditions.

Flowering Characteristics.

1. *Order and mode of flowering within the plant.*

The number of florets per head varies greatly not only in different plants but in different heads on the same plant, according to their position on the stem. From counts made in 1923 the average number of florets in the terminal heads of 200 plants each of three varieties was :—

	Number of florets. Average.	Extreme range.
English broad red ..	135.8	65—215
English late	143.3	85—275
Montgomery	140.3	55—215

While the number of florets per head within the plant may often range from about 10 to nearly 300, the greatest number is usually found on the main terminal heads and the smallest number on the late developed heads on some of the lower branches.

Only a few florets on a head open at the same time, those at the base of the head are usually the first, the others opening in more or less regular succession. It generally takes from 6 to 10 days according to the weather conditions for all the florets on a head to open.

The length of the flowering period also varies widely in different plants, but is generally much longer in the early flowering than in the late flowering varieties. In all normal plants it extends over several weeks. In 1922 the rates of flowering of three typical Montgomery plants were ascertained by counting and labelling with dated tags the newly-flowered heads every three days throughout the flowering period. For the purpose of these observations the heads were considered as being in bloom when one or more florets were fully open. The results are shown below, but in order to economise space they are expressed in terms of the percentage number of heads that flowered every six day period.

Plant no.	Total no. of heads.	July.		August.					September.		
		24	30	5	11	17	23	29	5	11	17
165 (86)	382	3	6	16	18	20	14	12	7	4	—
165 (107)	279	4	11	16	16	13	10	12	11	5	2
165 (318)	328	4	7	15	18	14	13	13	9	5	2

The total lengths of the flowering periods of these three plants, growing under spaced conditions, were 54, 64 and 61 days respectively. Even under ordinary conditions most plants are in bloom for 4 to 6 weeks.

The total number of flower heads on these three plants was 382, 279 and 328 respectively. As would be expected, the number of heads on spaced plants is considerably greater than on plants subjected to the severe competition of ordinary field crops. The number of heads per plant on 18 plants taken from an average crop of Montgomery red, kept for seed, ranged from 10 to 48, with an average of only 25.2 heads.

By labelling the heads of the three plants considered above as they came into flower, it was possible to determine their order of flowering in relation to their position on the stems. In every instance the terminal head of the main axis flowered first, while the order of flowering of the terminal heads of the side branches (numbered from the top) was :—second, third, first, fourth branches. In one plant the second side branches were on the average 11 days, the third 12 days, the first 13½ days, and the fourth side branches 17 days later than the main terminal heads on the same stems. In another plant the second branch was 11 days, the third 13 days, the first 17 days, and the fourth 22 days later.

The stems flower in a more or less regular sequence according to their order of development : the older stems on the periphery being the first to flower. The flowering sequence of the terminal heads of the main axes in the case of two plants was :—

Plant no.	July 24	July 30	August 5	August 11	August 17	August 23
86	17	18	12	2	1	2
107	12	20	8	7	3	—

The significance of these figures in relation to seed yields will be discussed later.

2. *The range of flowering within a population.*

Red clover, like all other exclusively cross-fertile species, is exceedingly variable; practically every plant is heterozygous for one or more characters. As the writer has previously shown (1927), there is an exceedingly wide range of variation in time of flowering between the plants within each variety; for instance, in 1924 the mean and the extreme ranges of the flowering periods of four varieties were :—

	No. of plants.	Time of opening of first flowers. Mean.	Extreme ranges.
English broad red ..	963	June 26th	June 5th—July 20th.
Vale of Clwyd	444	June 29th	June 6th—Aug. 5th.
English late	952	July 14th	June 14th—Aug. 5th.
Montgomery	549	July 25th	June 30th—Aug. 27th.
Cornish Marl	452	July 19th	July 2nd—Aug. 17th.

Other varieties have been found to be equally variable in this respect.

In view of the fact that there is a wide range in the time of flowering among the plants of the same variety—45 days in the English broad red, 52 days in the English late and 58 days in the Montgomery populations considered above—it is evident that only a proportion of the total number of heads which a crop is capable of producing will be ripe at the same time. Within the same variety, most of the heads on the early flowering plants are generally fully ripe before the late forms have started flowering. Fig. 1, which represents graphically the distribution of the time of flowering in 1922 of 330 plants of Montgomery late, and which may be regarded as typical of the flowering curves of most red clover varieties, clearly illustrates this point. In passing it may be mentioned that most other varieties have been found to give somewhat similar curves for time of flowering. In regard to Fig. 1 it will be noted that though the population showed an extremely wide flowering range extending from July 2 to September 9, yet about 42 per cent. of the plants came into flower within the comparatively short period of 9 days—July 23 to August 1, and about 67 per cent. flowered during the 15 day period—July 20 to August 4. The importance of this fact in connection with seed production will be considered later.

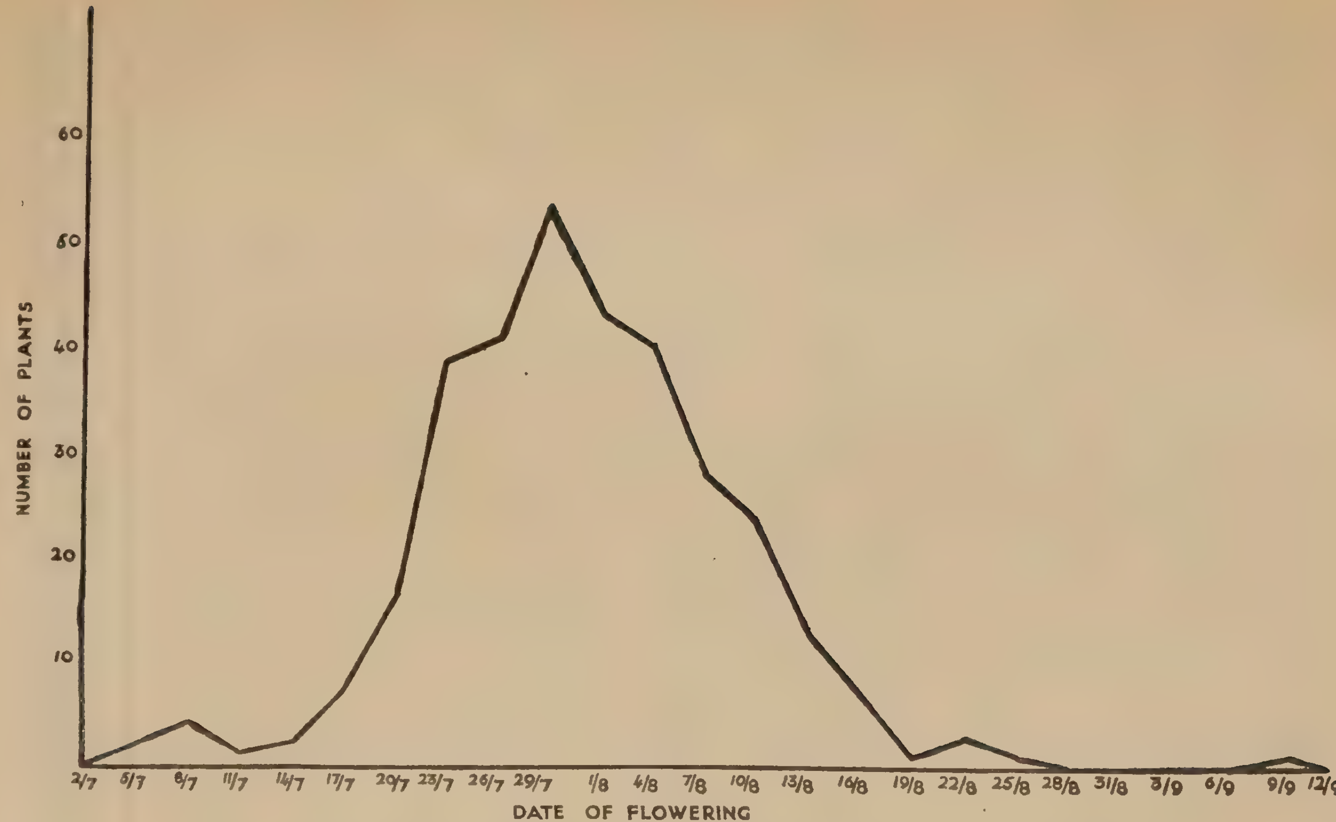

Fig. 1. Showing the distribution of the time of flowering of 330 plants of Montgomery red clover in 1922.

RIPENING AND QUALITY OF SEEDS.

1. *Time taken by seeds to ripen.*

In 1922 an experiment was undertaken with the object of ascertaining the length of time necessary for red clover seeds to become fully ripe. For this purpose three typical late flowering plants were protected from cross-pollination by enclosing them, just before they came into flower, in bee-proof cages with glass tops and wire gauze sides. When the plants were in full flower the cages were removed for 6 days—July 7th to 12th. During this period the plants were freely visited by bees. On July 12th all the open heads were labelled and the plants were again covered for a further period of 8 days, when the cages were finally removed. By this time practically all the florets on the heads that were in bloom when the plants were first exposed had withered ; all those which were still open together with all the heads that flowered later were picked off. Therefore the only flowers that produced seeds were those which had been pollinated during the 6 day period when the plants were first exposed.

Starting on the 9th September—30 days from the middle of the pollination period—4 to 5 heads were harvested from each plant, at random, every 4 days ; the last heads being harvested on October 3rd. After the heads had been dried the seeds were rubbed out by means of a small hand thresher. They were then counted, weighed and finally divided according to their general appearance into (1) plump seeds of good colour, and (2) brown and shrivelled seeds. The results are given in Table I.

TABLE I.—*Showing* (1) *the percentage number of plump seeds of good colour, and* (2) *the relative weight of all the seeds obtained from heads harvested from* 30 *to* 54 *days after pollination. The weights of the seeds are given in gm. per* 1000.

Date of harvesting.	No. of days after polli-nation.	Plant no. 84.		Plant no. 158.		Plant no. 256.	
		Good seeds. Per cent.	Weight in gm.	Good seeds. Per cent.	Weight in gm.	Good seeds. Per cent.	Weight. in gm.
9 September	30	64.7	1.170	62.6	1.349	82.4	1.743
13 ,,	34	77.9	1.680	69.9	1.493	77.4	1.785
17 ,,	38	77.2	1.747	52.2	1.511	82.4	1.759
21 ,,	42	44.7	1.635	32.4	1.239	47.0	1.256
25 ,,	46	38.9	1.729	28.1	1.214	42.4	1.213
29 ,,	48	40.6	1.511	38.1	1.120	34.4	1.250
3 October	52	18.3	1.556	33.3	1.282	0	1.210

There are several points of interest arising out of the results shown in Table I. In regard to general colour, there was but very little difference between the seeds harvested 30, 34 and 38 days after pollination ; all three samples had altogether

better coloured seeds than those harvested later. After September 17th the seeds became successively poorer at each harvest, in that they contained an increasing number of brown seeds. It should be explained that the weather during the latter half of September was rather wet. It is clear, therefore, that once the seeds are fully ripe they rapidly lose their bright colour in wet weather and become brown if the plants are left standing in the field. In dry weather the fully ripe seeds will retain their colour for a moderately long time. It has been observed repeatedly that seeds retain their colour under glass-house conditions far longer than in the open. The discolouring of the seeds in wet weather is partly explained by the fact that the anthocyanin pigment, to which the seeds owe their purple colour, is soluble in water. Probably this is also the explanation why the seed grown in countries with more equable climates than Britain, such as Canada, New Zealand, Chile and Italy, generally contains far smaller proportions of brown seeds than that grown in this country. It is also significant that the seed grown in the east of England is generally brighter in colour than that grown in Montgomeryshire or Cornwall.

The seeds obtained in this experiment were not tested for germination capacity, but it will be shown later that the percentage germination of brown seeds, even when harvested from fully ripe heads, is on the average very considerably lower than that of good coloured seeds. On reference to Table I it will be seen that there was a definite connection between the weight of the seeds and their general colour ; in nearly every case an increase in the number of brown seeds was accompanied by a reduction in the weight of the seeds. It will be shown later when discussing hard seeds that while the seed coats of a very large proportion of bright coloured seeds are impermeable to water, the testæ of brown seeds are very permeable. It is therefore not improbable that the reduced weight of the brown seed is due to actual loss of water as the result of transpiration through the pervious seed coat.

In all three plants the seeds harvested 34 days after pollination were heavier than those harvested 4 days earlier, while in two plants the seeds harvested 38 days after pollination were slightly heavier than those harvested 34 days after pollination. It seems therefore that at least in two plants, viz., nos. 86 and 158, the seeds harvested on September 9th, that is about 30 days after pollination, were not fully developed. Taking both the colour and weight of seed into consideration, the best seeds were those harvested about 34 to 38 days after pollination. It does not necessarily follow that the optimum time of harvesting red clover seed in all cases is about 5 weeks after pollination. During the course of his breeding work on red clover, the writer has obtained evidence indicating that the rate of development of the seeds depends to a very large extent on the time of year the flowers are cross-pollinated. The seeds from crosses made during early- and mid-summer mature much more rapidly than those from crosses made in the autumn. As a general rule the crosses made during May and June are ripe in about 28 days, those made during July and the earlier part of August in about 30 to 38 days, those in the latter part of August and in September in about 38 to 48 days, while the crosses made during October take from 50 to 60 days to develop, even under glass.

The effect of the season on the rate of development of the seeds was clearly brought out by a small experiment conducted in 1922 on two open pollinated plants. These two plants had extended flowering periods ranging in one case from July 11 to October 3, and in the other case from July 14 to October 10.

As the flower heads opened, they were labelled every 6 days with dated tags. These heads were harvested 35 days later, that is about 35 days after they had been pollinated, and when dry they were threshed and the seeds weighed. To facilitate comparison the weights are given in terms of the weight of 1000 seeds for each date.

Mean time of flowering.	Plant no. 1.	Plant no. 2.
2/8	1.38	2.08
8/8	1.39	2.11
14/8	1.19	1.89
20/8	0.97	1.47
26/8	0.62	1.25
2/9	—	1.17

It will be seen from the above results that the heads flowering during the latter part of August and the first week in September produced in both plants altogether lighter seeds than those flowering during the earlier part of August. It is, however, probable that this very marked difference in the weight of the seeds may not be entirely due to the effect of the season. The heads that flowered late in the season were those situated on the lower branches, and it is possible that the seeds produced by them are smaller and less plump than those from the terminal heads of the upper branches.

2. *The general appearance of the heads as an indication of the stage of ripeness of the seeds.*

In 1925, a favourable year for production of red clover seed in this district, 18 plants taken at random from about 2 acres of Montgomery red clover were pulled up *in toto* the day the crop was cut for seed. The field was in its first harvest year. It had been fairly well grazed up to May 31 before it was put up for seed. The crop was in full bloom about July 26—31, and it was deemed ripe about the end of August, and was cut on August 31. In the main the conditions were favourable for pollination, the bees being very numerous, particularly during the warm sunny period which occurred when the crop was in full bloom. The average yield of dressed seeds was about 2½ cwt. per acre.

All the heads on the plants that had been pulled up were immediately divided and labelled according to their stages of ripeness as indicated by the general colour of the calyces and upper part of the stems. These stages were :—

(I) Seeds hard and rubbed out quite readily. All calyces completely brown, and the upper part of the stems also distinctly brown.

(II) Seeds hard and rubbed out readily. All calyces completely brown, but the upper part of the stems yellowish brown.

(III) Seeds hard and rubbed out fairly readily. Calyces mainly brown, and upper part of the stems green.

(IV) Seeds fairly hard, but rubbed fairly poorly. About 50 to 75 per cent. of the pods with brown calyces, others yellowish green. Stems green.

(V) Seeds fairly hard but rubbed out with difficulty. About 50 per cent. of the pods with light brown or greenish yellow calyces, others green. Stems green.

(VI) Seeds fairly soft and did not rub out. A few of the pods with slightly brown calyces. Stems green.

(VII) Seeds soft but fairly well developed. Calyces all green.

(VIII) Seeds soft and poorly developed. Calyces green.

(IX) Recently pollinated, with all the corollas withered.

(X) Recently pollinated, with only the corollas of the lower florets withered.

After labelling of the heads, the plants were placed in the open to dry for eight days—the length of time required to dry the main crop. The first three days of this period were dry and sunny, but the next four days proved very wet, while the eighth day was quite dry.

When the plants were brought in the heads were carefully examined, and the extent to which they had shed and sprouted was noted. After about three months' storage the heads were cut, arranged in their appropriate classes for each plant, and then threshed. The seeds in each class were first counted and weighed and then divided into two categories according to their general appearance, viz., (1) plump seeds of good colour, and (2) brown and shrivelled seeds. They were then tested for germination; for this purpose, however, the seeds from the 18 plants were bulked together into their respective classes.

Since only 2 or 3 plants had heads representative of all the ten stages into which they were divided, it is evident that the numerical means would not form a true basis of comparison; strictly comparable results were obtained by using the Student's method—by which only paired readings are compared. For this purpose stage III, which happened to be the only stage represented on all the plants, was taken as the standard of comparison: so that for each plant all the other stages were compared directly with stage III on the same plant. The results are summarized in Table II.

The number of plants compared in different stages were—stages I and VII—13 each; stage II—11; stages IV, V and VI—14, and stage VII—8. As was expected, no seeds were obtained from heads in stages IX and X. On reference to Table II it will be seen that as regards colour and general appearance the best seeds were those from stages I and II. It is, however, a noteworthy fact that seeds in stage I were far more variable than those in stages II, III and IV in respect to general colour. In some plants over 90 per cent. of the seeds in stage I had a very good colour, others had a high proportion which, though classified as "good," were rapidly becoming discoloured, while two plants gave no good seeds in stage I, every seed being badly weathered. It is evident that had the seeds been exposed to wet weather for a few more days the proportion of good seeds in stage I would have been very materially reduced. It will be seen from Table II that the quality of seeds as judged by colour decreases fairly appreciably from stage I to stage VIII. As regards seed weights there was no difference between those of the seeds from stages I, II, III and IV. Seeds of stage V are 0.166 gm. per 1000 lighter than those of stage III, the odds that this difference is not due to chance being about 65 : 1. Seeds of stages VI, VII and VIII are very significantly lighter; those of stage VIII being about only one-quarter the weight of those of stage III.

The germination results conform in the main to the colour and weight data. The best results were given by seeds of stages II and III, which gave germinations of 96.2 and 95.6 per cent. respectively. The seeds from stages I and IV gave slightly poorer germinations—90.1 and 91.3 per cent. respectively. The

TABLE II.—*Showing* (1) *the percentage number of seeds of good quality,* (2) *weight per* 1000 *seeds, and* (3) *percentage germination of all the seeds obtained from heads in different stages of ripeness. Results* (1) *and* (2) *are compared according to the Student's method with stage* III *as the standard throughout.*

Stage of ripeness.	Good quality seed.			Total seeds (good quality and brown seeds).				
	Percentage.			Weight per 1000 seeds in gm.				
	Stages other than III.	Stage III.	Gain or loss of stage III as compared with the other stages.	Stages other than III.	Stage III.	Gain or loss of stage III as compared with the other stages.	Approximate odds.	Percentage germination.
I ..	70.0	52.9	— 17.1	1.806	1.838	+ .032	1 : 1	90.1
II ..	68.1	55.4	— 12.1	1.826	1.794	— .034	2 : 1	96.2
III ..	—	—	—	—	—	—	—	95.6
IV ..	44.8	54.5	+ 9.7	1.777	1.839	+ .062	3 : 1	91.3
V ..	42.3	53.9	+ 11.6	1.631	1.797	+ .166	65 : 1	87.8
VI ..	39.2	61.1	+ 21.9	1.468	1.839	+ .371	1300 : 1	50.4
VII ..	30.4	50.7	+ 20.3	1.250	1.827	+ .577	9999 : 1	31.6
VIII ..	14.9	60.7	+ 45.8	0.490	1.910	+ 1.425	9999 : 1	5.2

germination of the seeds in stage V was moderately good, but significantly poorer than that of the seeds of stages I—IV : seeds of stages VI and VII gave only 50.4 and 31.6 per cent. germination respectively, while only 5.2 per cent. of those of stage VIII germinated.

It is evident, therefore, taking the three characters—colour, weight and germination—into consideration, that the best quality seeds were obtained from stage II, that is, from the heads in which all the calyces were brown and the stems below the heads were yellowish green, but stages I, III and IV also contributed quite a fair quota of good quality seeds. Stage V gave a fair number of good seeds, but the contributions of stages VI, VII and VIII are very small. It may be safely concluded from these results that in order to obtain the maximum yield of first grade seeds the crop should be cut when most of the heads are in the condition represented by stages I to IV.

Somewhat similar results have been obtained by Witte (1921 *a*) and Sutton and Jones (1927). Witte found from his investigations that the best seeds were obtained from heads harvested when the calyces were completely withered and the upper part of the stem green. Sutton and Jones obtained the best seeds

from a slightly earlier stage—from heads in which the calyces were half brown. Apparently this stage corresponds with stages III and IV of the present experiment.

3. *Development of the seeds after cutting.*

As already pointed out, a certain proportion of the seeds even from very under-ripe heads, such as those in stages V and VI in Table II, germinated quite normally. When the plants were cut the seeds were still in the soft dough stage. It appears, therefore, that a certain amount of development takes place in the immature seeds after the plants have been cut back. This point was put to the test in 1928. Five plants with heads in different stages of ripeness were selected and cut in October. Immediately the plants were cut, a number of heads in three quite distinct stages of ripeness were selected and labelled on each plant. The stages chosen for this purpose were :—

I Seeds fully ripe ; calyces and upper part of the stems brown.

II Seeds fairly hard, but all calyces green.

III Seeds about half developed, calyces green.

About half the number of heads on each plant were then cut, leaving about one inch of the stem attached, while the remainder were left on the stems to ripen. The heads were threshed after three months' storage and the seeds weighed : the results, given as the average weight in gm. per 1000 seeds, are shown below.

Treatment of heads.	Stages of ripeness of the heads. I Ripe.	II Under-ripe.	III Very under-ripe.
(*a*) Left on the stems ..	1.912	1.512	1.307
(*b*) Cut	1.895	1.396	1.135
Gain of (*a*) over (*b*) ..	+.017	+.116	+.172

The results obtained were in accordance with expectation. Though there was practically no difference in weight between the seeds from the ripe heads, in the case of the under-ripe heads the seeds from those left to mature on the stem showed a marked increase in weight as compared with the seeds of the heads cut soon after the plants were harvested, indicating that under normal conditions of drying there is quite a considerable flow of food material from the stem to the immature seeds after the plants have been cut. The practical implication of this is that the drying of a red clover seed crop should be very gradual ; if the drying is too rapid the transport of food material for the further development of the immature seed is at once stopped.

4. *Shedding and Sprouting.*

As already stated, before the 18 plants referred to on page 66 were brought in prior to storing, all the heads were carefully examined in order to ascertain the extent to which they had shed and sprouted. The percentage number of heads in each stage that were then shedding and sprouting is given below. In considering these figures it should be borne in mind that the weather during the 8 days the plants were left in the open was particularly favourable to both shedding and sprouting.

		Stages of ripeness.							
		I	II	III	IV	V	VI	VII	VIII
Percentage no. of heads	Shedding	48	20	15	17	6	1	0	0
	Sprouting	20	11	6	7	3	0	0	0

As was expected, there was a close connection between the extent to which the heads were shedding and sprouting and their stage of ripeness. For example, in the case of the fully ripe heads (stage I) as many as 48 per cent. were shedding and 20 per cent. sprouting, but in the case of slightly less ripe heads (Stage II) only 20 per cent. were shedding and 11 per cent. were sprouting : while the proportion in stage III was still less—15 per cent. shedding and 6 per cent. sprouting. These results indicate that in wet weather there is a great risk of losing a considerable proportion of the best seeds as the result of shedding and sprouting if the crop is over-ripe. It should be mentioned that many of the heads in stage I, and to a lesser extent in stage II, were showing signs of shedding in the field before the plants were cut.

The different plants also showed wide differences in regard to the readiness with which they shed and sprout when ripe. Considering only the heads in stages I to IV, in the case of one plant from 42 to 55 per cent. and in another plant 13 to 50 per cent. of the heads in these four stages were more or less badly shed. These formed very marked contrasts to two other plants, one of which had no heads shedding and the other only one. Differences of the same order were found between the plants in regard to sprouting.

5. *Number of seeds from heads in different stages of ripeness.*

The figures below give the average number of seeds per head for each stage.

	Stages of ripeness.									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Average no. of seeds per head ..	49.8	57.6	53.6	50.7	43.3	40.8	34.2	6.2	0	0

The figures for stages I to VII are strictly comparable, as only those plants with heads in all the seven stages were taken into consideration when computing the averages. It will be observed that the average yield of seeds from the heads in stage I was appreciably less than that of stages II and III ; as the weather conditions were very favourable to pollination during the time the heads in stage I were in flower, the reduced yield from these heads is very probably entirely due to shedding. There are no significant differences in the number of seeds from stages II, III and IV, from which the best yields were obtained. The reduced yields given by the heads in stages V to VIII are explained partly by the fact that the weather conditions during the latter part of the season were less favourable to pollination, and partly by the fact that some of the very light seeds were lost during threshing and winnowing.

There were very wide differences between the individual plants in respect to the number of seeds produced. As shown by the following figures, which represent the average number of seeds per head for a few contrasting plants, some plants gave consistently high average yields in all except the very under-ripe stages, while others gave uniformly low yields for all stages.

Percentage number of seeds from heads in different stages of ripeness given by three high and three low yielding plants.

	Plant no.	I	II	III	IV	V	VI
High yielding plants	4	—	112.5	100.1	—	46.5	60.0
	15	83.7	86.5	77.0	94.0	—	49.7
	7	79.5	62.2	74.0	59.0	46.7	46.2
Low yielding plants	18	36.1	35.0	29.0	25.0	9.0	16.0
	16	45.0	—	31.0	26.5	—	34.4
	8	35.0	20.5	—	48.0	23.0	19.0

The actual number of florets was not counted in this particular instance, but from general observation the plants did not appear to differ a great deal in this respect, certainly not to such a degree as to account for the very marked disparity in the number of seeds obtained. Moreover, further evidence could be adduced from other sources to prove that the degree of fertility, though greatly influenced by environmental factors, is an inherent characteristic which varies within wide limits in different plants.

6. *Number of heads in different stages of ripeness.*

In view of the fact that the crop from which these plants were taken was considered from a practical point of view fully ripe when cut for seed, it will be interesting to compare the number of heads in the different stages of ripeness obtained from these plants. The average percentage number in each stage was as follows :—

Stages of ripeness.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Percentage no. of heads	19.2	11.1	11.1	9.9	7.7	15.5	15.5	8.1	0.7	1.2

As already pointed out on page 68 the amount of good quality seed yielded by the under-ripe heads represented by stages VI to X, which constituted 41 per cent. of the total heads harvested, was so small as to be almost negligible ; in practice most of the seeds would be discarded during cleaning operations as tailings. It is therefore clear, if the plants investigated are assumed to be truly representative of the crop as a whole, that only 59 per cent. of the total heads actually harvested produced seeds of any commercial value. If the heads in stage V, the seeds from which were of doubtful value, be excluded, the proportion of effective heads is further reduced to little over 50 per cent. It is difficult to see how this proportion could have been increased in this particular case. It is true if the cutting had been put off for another week the heads in stages IV to VIII would have yielded an appreciably higher proportion of seeds of good quality. It is, however, probable that this increase would have been more than counterbalanced, particularly since wet weather intervened, by a decrease in the yield of good seeds from stages I and II due to shedding, sprouting and discoloration. Had the weather remained fine and dry, there is no doubt a considerably larger yield of first quality seeds would have been obtained if the crops had been allowed to remain standing a few days longer. Under

our unreliable weather conditions it is always advisable to err on the side of cutting too early, not only for the reasons given above, but also to avoid loss through shedding of the best developed seeds which are usually obtained from the terminal heads of the main stem, which are invariably the first to come into flower.

Relation between time of flowering and seed yield.

It has been shown on page 62 that owing to their extremely heterozygous character all varieties of red clover are exceedingly variable in regard to time of flowering: in all varieties some plants flower about 40 to 60 days earlier than others. It has, however, been found that with each variety the distribution of the flowering times of the individual plants conforms fairly closely to a normal frequency curve. The general distribution in the time of flowering of the population of Montgomery illustrated in Fig. 1, page 63, may be regarded as being fairly typical of all the other varieties. In this particular Montgomery population the percentage weekly distributions were as follows:—

	July				August			
Date.	10	17	24	31	7	14	21	28
Percentage ..	2.2	2.8	21.7	23.0	35.5	12.8	1.7	0.3

It will be seen that although the flowering extended over a period of 8 weeks, as many as 35.5 per cent. of the plants came into flower during the week August 1 to 7, and 58.5 per cent. during the two weeks July 25 to August 7. The time during which the greatest number of plants come into bloom varies widely in different varieties. This is clearly brought out by the figures below giving the appropriate periods for a few varieties in 1925, during which about 50 per cent. of the plants came into bloom. It should be noted that these periods only refer to the first bloom; the periods of maximum bloom would be about 10 days later.

Early varieties.

American medium..	June 10—18
English broad red	June 10—22
Vale of Clwyd	June 14—26

Late varieties.

English	July 8—16
Cornish marl	July 12—20
Swedish late	July 16—28
Montgomery	July 16—28

Since cross-pollination in red clover is effected almost exclusively by humble bees, the yield of seeds will necessarily be very largely governed by the number of bees present when the crop is in maximum bloom. The investigations carried out by the writer concerning the relation between the frequency of bees and the time of flowering of red clover have been reported in a previous publication

(1925). It was found that humble bees were most frequent on red clover from the second to the fourth week in August. From the first to the third week in July only very few bees were present: the number increased very rapidly during the last week in July and the first week in August, and reached its maximum during the second and third weeks in August. After the second week in September the numbers decreased rapidly. Reference to the time of flowering of different varieties shown on page 62 brings out the interesting fact that the periods of maximum bloom of all the varieties fall considerably earlier than the period during which the useful bees are present in greatest numbers, namely, the first to the fourth week in August. The first growth of the early varieties is in full flower some considerable time before the workers of the most important red clover pollinators, viz., *Bombus hortorum* and *B. agrorum*, have emerged, while the few queens generally found in these first crops are totally inadequate to pollinate the crops. On this account the first crops of the early varieties are always mown for hay and seed invariably harvested from the second crops. In order that the period of maximum bloom of the second crops may coincide with the period of greatest frequency of the bees, it is essential that the crops be mown early, not later than the third week in June. Even Montgomery, which is one of the latest varieties in cultivation, flowers about two weeks too early to take full advantage of the period of maximum bee activity. In order to delay the flowering so that the two periods coincide, the usual practice in the case of the late varieties is to graze the crops during the early part of the summer. Montgomery and Cornish marl can with advantage be grazed up to the first week and English late to the second and in early districts to the third week in June. The point that should be kept constantly in mind when arranging the cutting or grazing is that the time of maximum bloom should be made to coincide with the period of greatest number of useful bees. If the weather during this period proves favourable for pollination then the best time for cutting the crops for seed is approximately five weeks from the middle of this period. Should the weather prove unfavourable during any part of this period, the time of cutting should be adjusted accordingly, provided of course the weather conditions at the time are favourable for harvesting. The two most important periods of the year, both from the point of view of quality and yield of seeds, are the time of maximum bloom and the time of harvesting. Not only is it essential in order to secure seed of good quality that the crops should be harvested in good condition at the right time, but it is also equally, if not more, important from the point of view of seed yield that the weather during the pollination period should be warm and sunny. Apart from the fact that wet weather has the effect of restricting the pollinating activities of the bees, the pollen itself is rendered non-viable when it comes into contact with water.

Seed weights.

1. *Seed weights of different varieties and nationalities.*

The data that will be considered in this connection were obtained on seed harvested in 6 years during the period 1918 to 1928. During this period a large number of samples were collected from various sources for inclusion in the comparative variety trials. In most cases the seed weights, which were determined primarily for the purpose of calculating the appropriate seed rates for sowing, were obtained by weighing from each sample two lots of 500 seeds each.

By duplicating the weighings in this way it was possible to detect at once any error in sampling and weighing. Although 508 samples representative of 25 varieties and nationalities have been weighed, the data, particularly in the case of a few varieties, are by no means complete owing to the fact that in some years no samples of certain varieties were received, while in other years the numbers were too few to give trustworthy results, and are therefore not shown. The average results in gm. per 1000 seeds are given in Tables III, IV and V. Table III shows the frequency distributions of the seed weights of different samples harvested in the same year ; Table IV gives the average annual weights for different years for some of the most important varieties, while Table V shows the total average weights of the different varieties. The averages given in Table V were calculated according to the Student's method, by comparing directly the average annual weights of each variety with those of English broad red in the corresponding years.

TABLE III.—*Showing for certain varieties the frequency distributions of the weights (gm. per 1000 seeds) of different seed samples harvested in the same year.*

			Class Centres.											
Year	Variety.	No. of samples.	1.35	1.45	1.55	1.65	1.75	1.85	1.95	2.05	2.15	2.25	2.35	2.45
1918	English broad red	21	—	—	1	3	3	4	5	2	2	1	—	—
	English late ..	18	—	—	—	1	3	3	6	1	4	—	—	—
	Canadian	10	—	—	1	2	4	3	—	—	—	—	—	—
	Chilian	17	—	—	—	—	—	—	4	5	2	—	4	2
1921	English broad red	51	—	—	2	7	10	20	10	1	1	—	—	—
	English late ..	9	—	1	1	1	1	3	2	—	—	—	—	—
	Montgomery ..	12	1	—	2	3	5	—	1	—	—	—	—	—
	American medium..	13	—	—	2	8	1	1	1	—	—	—	—	—
	New Zealand ..	12	—	—	—	—	—	—	1	8	1	2	—	—
	Chilian	—	—	—	—	—	—	—	3	2	5	4	—	—
1923	English broad red	25	—	—	—	3	4	6	4	6	1	1	—	—
	English late ..	27	—	—	—	1	4	14	2	3	1	1	1	—
	Montgomery ..	20	—	—	—	4	5	6	4	1	—	—	—	—
	Swiss	—	—	—	—	4	—	2	—	—	—	—	—	—

The results given in Table III bring out one important fact, namely, that the seed weights of the different samples are more variable in some varieties than in others. It is very significant that the home-grown varieties Montgomery, Cornish marl, English late, Vale of Clwyd and English broad red showed a greater degree of variability in this respect than most of the foreign clovers. The most uniform samples were those from Canada, the United States, Chile and New Zealand. The greater uniformity of many of the foreign seeds is probably explained partly by the fact that they are often carefully blended before they

TABLE IV.—*The average seed weights (gm. per 1000 seeds) for various varieties in different years.*

Varieties.	1918			1919			1921			1922			1923			1927			1928		
	No. of samples.	Gm.	P.E.	No. of samples.	Gm.	P.E.	No. of samples.	Gm.	P.E.	No. of samples.	Gm.	P.E.	No. of samples.	Gm.	P.E.	No. of samples.	Gm.	P.E.	No. of samples.	Gm.	P.E.
Earlies.																					
English broad red ..	21	1.88	±.028	5	1.80	±.045	51	1.75	±.012	3	1.94	—	25	1.91	±.019	5	1.78	±.040	5	1.95	±.045
Vale of Clwyd ..	—	—	—	—	—	—	11	1.82	±.020	3	1.94	—	6	2.01	±.041	—	—	—	3	1.88	±.075
French and Brittany ..	—	—	—	5	1.89	±.042	11	1.80	±.030	—	—	—	—	—	—	3	1.69	—	—	—	—
Italian	15	1.73	±.021	3	1.79	±.056	3	1.62	±.020	—	—	—	—	—	—	3	1.58	—	—	—	—
Swiss	—	—	—	—	—	—	3	1.75	±.077	—	—	—	6	1.71	±.027	4	1.75	±.045	—	—	—
Canadian	10	1.72	±.023	—	—	—	3	1.87	—	8	1.72	±.038	—	—	—	—	—	—	—	—	—
American medium ..	4	1.75	±.048	4	1.62	±.040	13	1.70	±.020	5	1.73	±.041	—	—	—	3	1.62	—	—	—	—
Chilian	17	2.17	±.032	3	2.33	—	14	2.26	±.020	3	2.26	±.010	—	—	—	3	2.15	—	—	—	—
New Zealand	—	—	—	3	2.17	—	12	2.10	±.031	3	2.19	—	—	—	—	3	2.07	—	—	—	—
Lates.																					
English late	18	1.93	±.017	3	1.83	—	9	1.65	±.036	3	1.83	—	27	1.98	±.024	6	1.82	±.044	3	1.93	±.062
Montgomery	6	1.61	±.037	—	—	—	12	1.68	±.031	3	1.91	—	20	1.83	±.017	5	1.46	±.072	—	—	—
Cornish marl ..	4	1.67	±.056	3	1.56	—	4	1.42	±.012	3	1.70	—	—	—	—	—	—	—	—	—	—
Swedish late	—	—	—	3	1.93	—	4	1.75	±.050	—	—	—	—	—	—	14	1.75	±.025	2	1.43	—
American Mammoth	—	—	—	2	1.58	—	6	1.64	±.048	4	1.62	±.158	—	—	—	3	1.69	—	—	—	—
Wilds	—	—	—	—	—	—	3	1.40	—	3	1.59	—	3	1.29	—	2	1.48	—	2	1.57	—

are placed on the market, whereas a very considerable proportion of the home-grown seed is often sold direct from the grower to the farmer as small unblended lots, and partly by the fact that they are grown under drier and more equable climatic conditions than our own. The latter view receives a certain amount of support from the figures in Table IV. Although as shown in this table the average seed weights of samples differ considerably from year to year in all varieties, the fluctuations were rather more marked in the home-grown varieties than in many of the foreign clovers ; Montgomery and Cornish marl, which are grown in districts in which the rainfall is on the average appreciably higher than in the areas where English broad red and English late are grown for seed, were more variable than the latter. The extreme variability of red clover seeds grown in the western districts is demonstrated by the following figures, which represent the weights, percentage germination and purity of the seed of the same strain grown in different years on the same farm.

	Harvest years.					
	1919	1921	1922	1923	1924	1926
Weight per 1000 seeds (gm.)	1.57	1.60	1.70	2.00	2.02	1.57
Percentage germination	77	79	94	85	72	82
Percentage hard seed	11	18	2	3	4	7
Percentage purity	97.5	100	97.1	98.0	94.5	98.5

TABLE V.—*The total average seed weights of different varieties over a number of years. These averages were calculated according to the Student's method with the average weights for English broad red as the standard of comparison throughout.*

Varieties.	No. of years.	Weights per 1000 seeds in gm.		Gain (+) or loss(—) of broad red, compared with other varieties.	Z.	Approximate odds.
		Varieties shown in column 1.	English broad red.			
Chilian	6	2.29	1.85	— .44	3.12	—
New Zealand	3	2.15	1.83	— .32	4.57	90 : 1
Czechoslovakian ..	3	1.86	1.78	— .08	.87	5 : 1
Swedish late	4	1.84	1.81	— .03	.49	3 : 1
Vale of Clwyd	4	1.91	1.89	— .02	.25	2 : 1
English late	8	1.86	1.87	+ .01	.18	2 : 1
French and Brittany ..	4	1.78	1.82	+ .03	.23	2 : 1
Canadian	3	1.74	1.86	+ .12	1.17	13 : 1
Italian	4	1.68	1.80	+ .12	1.62	26 : 1
Russian late	2	1.71	1.87	+ .16	2.29	7 : 1
American medium ..	5	1.66	1.82	+ .16	2.80	400 : 1
Montgomery	6	1.69	1.86	+ .17	.85	—
American Mammoth ..	4	1.63	1.82	+ .18	1.78	35 : 1
Cornish marl	6	1.59	1.84	+ .24	1.36	76 : 1
Wild	6	1.47	1.87	+ .39	2.82	416 : 1

If Table V be examined it will be seen that while a number of varieties and nationalities show no significant differences in respect to their average seed weights, others, despite the fact that they exhibit wide fluctuations from season to season (see Table IV), show very marked differences ranging from 1.47 gm. per 1000 seeds in the case of wild red to 2.29 gm. in the case of Chilian, when the weights are compared over a number of years. The heaviest seeds were given by Chilian and New Zealand clovers, both being significantly heavier than English broad red. In comparison with English broad red the seeds of Czechoslovakian, Swedish and Vale of Clwyd were on the average very slightly heavier, while those of English late, French and Brittany were very slightly lighter, but, as the odds indicate, the differences between these six varieties are too small to be significant. Canadian, Italian, American Mammoth and Montgomery were on the average significantly lighter than English broad red, though the differences were not very great. The lightest seeds were those of Cornish marl and wild red. In this connection it is interesting to note that Stapledon (1920) found that seeds emanating from Canada, Italy and France were appreciably lighter in weight than those from Britain and Chile.

2. *Intra-varietal seed weight variation.*

Data relating to the seed weights of a number of plants of four varieties harvested in 1921, 1922 and 1925 are given in Table VI. The weights for one and the same year are strictly comparable, as the plants were of the same age and were grown on the same piece of ground and under similar conditions as regards tillage and manuring. As an additional precaution care was taken that the heads harvested—only terminal heads on the main stems were taken—were dead ripe, and that the seeds weighed were fully developed and of good colour. Except in the case of a few less prolific plants, 500 seeds per plant were weighed.

As indicated in Table VI for all the four varieties investigated, the different plants within the same population show very wide differences in respect to their seed weights; for example, in the case of English broad red the seed weights of the 33 plants harvested in 1921 ranged from 1.25 to 2.15 gm. per 1000 and of the 70 plants harvested in 1925 from 1.25 to 2.45 gm. It is interesting to note that the ranges given by the four varieties were of the same general order; all four had light and heavy seeded plants with all grades of intermediaries. Both English late and English broad red contained some exceedingly heavy seeded plants; one plant of English late harvested in 1921 had particularly large seeds weighing 2.65 gm. per 1000, an extraordinarily heavy weight for red clover seeds.

It is worthy of note that while there was no significant difference between English broad red and English late in regard to their mean seed weights, the seeds of these two varieties were slightly but significantly heavier than those of Altaswede.

Very similar results to these reported above have been obtained by Malte (1912) in Canada. The seed weights of the plants studied by Malte varied from about 1.20 to 2.49 gm.

As already pointed out by Malte, there appears to be no doubt that the size of the seeds in red clover, though subjected within certain limits to environmental fluctuations, is a definitely heritable characteristic. Although the writer has not actually carried out any genetical studies on this particular character, he has

TABLE VI.—*The frequency distribution of seed weights (gm. per* 1000 *seeds) of different plants of a few red clover varieties.*

Year	Variety.	No. of plants.	Class centres. 1.15	1.25	1.35	1.45	1.55	1.65	1.75	1.85	1.95	2.05	2.15	2.25	2.35	2.45	2.55	2.65	Means.	P.E.
1921	English broad red	33	—	1	1	8	9	3	3	5	1	1	1	—	—	—	—	—	1.629	±.0472
	English late ..	16	—	2	1	1	5	1	1	2	2	—	—	—	—	—	—	1	1.669	±.0681
1922	Montgomery ..	34	1	2	1	6	4	5	5	5	4	1	—	—	—	—	—	—	1.647	±.0536
1925	English broad red	70	—	1	2	4	10	10	16	7	9	3	4	2	—	2	—	—	1.777	±.0473
	English late ..	37	—	—	2	5	2	3	6	7	3	5	2	1	1	—	—	—	1.767	±.0526
	Altaswede ..	125	1	4	9	12	23	22	20	19	8	5	1	1	—	—	—	—	1.664	±.0588

obtained considerable evidence during the course of his breeding work on red clover which indicates that the size of seeds is definitely inherited. For example, many of the families obtained by close inbreeding show very striking differences in regard to this character ; some have uniformly small seeds ranging in weight from about 1.10 to 1.50 gm. per 1000 seeds, while others have moderately large seeds ranging in weight from about 1.80 to 2.30 gm. per 1000 seeds.

Relation between colour and weight of seeds.

One of the most striking characteristics of red clover seeds is their extreme variability in regard to colour. In every sample, seeds may be found ranging in colour from yellow of various tinges through purple of varying shades and intensities to violet black, while brown seeds of various shades are also usually present. Although this wide range of colours may be found within every variety of red clover, all the normally developed and ripe seeds within any given plants have, as previously shown by Malte (1912), Witte (1921 *b*), and others, the same general colour. In recent years the writer has made an intensive study of the genetics of various characters in red clover, including seed coat colour. These investigations, the results of which will be reported in a future paper, have already thrown a good deal of interesting light on the modes of inheritance of the various seed colours and their inter-relationship. For instance, it has been definitely found that white seed coat colour is recessive to yellow, and that yellow is recessive to various shades of purple. It has been further shown that in some families the purple pigment is due to the presence of complementary factors, while in others it is determined by multiple factors.

During the last two or three decades much time and thought have been devoted to the study of the relationship between the colour and weight of red clover seed, but the results obtained by the different workers are so contradictory that no apology is necessary for going over the same ground again. Most investigators—Fruwirth (1906), Kajanus (1912), Eastman (1912), Stapledon (1920), to mention only a few—have found that the purple seeds in commercial samples are heavier than the yellow seeds. Haberlandt (1897) and von Rümker (1893) on the other hand came to the conclusion that yellow seeds were heavier than purple. As a result of investigations on individual plants Bauman (1911) and Holdefleiss (1913) reported that the yellow seeds in their material were lighter in weight than purple seeds, but both Malte (1912) and Kajanus (1912) found there was no correlation between weight and colour of seed.

It is very probable that these discrepancies between the results obtained by the different investigators may be explained on the grounds that in some cases it was not sufficiently realized that there is a very close connection between the colour of the seeds and the stage of ripeness at which they are harvested. During the early stages of development up to the late dough stage all seeds are green, but as they ripen the green colour is soon replaced by a yellow pigment, which in turn changes—very gradually in some plants, rapidly in others, according to their genotypic constitutions—into purple in the purple seeded plants. Yellow seeds may, therefore, be of two distinct kinds, one, in the case of genetically yellow seeded plants, in which the yellow colour represents the final stage of development, and the other in genetically purple seeded plants in which the development has been arrested by harvesting the seeds before they are fully ripe. The data below showing the percentage number of deep purple,

light purple, yellow and brown seeds obtained from under-ripe and ripe heads harvested from two purple seeded plants illustrate very well the change in the colour that takes place as the seeds ripen.

Plant no.	Stage of ripeness of the heads.	Percentage number of seeds of different colours. Deep purple.	Light purple.	Yellow.	Brown.
1	Under-ripe	11.4	24.3	56.1	8.2
	Ripe	35.2	35.1	17.6	12.1
2	Under-ripe	7.5	22.7	65.1	4.7
	Ripe	22.7	34.9	32.5	9.7

As may be expected on *a priori* grounds the purple seeds since they are rather more developed are on the average perceptibly heavier than the yellow seeds harvested from the same plants. This fact is clearly brought out by the following figures giving the weights (gm. per 1000 seeds) of (1) deep purple, and (2) very light purple and yellow seeds from three different plants.

Plant no.	Deep purple seeds.	Very light purple and yellow seeds.
1	1.686	1.390
2	1.692	1.261
3	1.941	1.632

In this connection it should be noted that the brown seeds, generally found in most samples, may also be of two distinct kinds ;* one is the result of the arrested development which occurs, for instance, when the plants are cut while the seeds are still in the milk stage, and the other is brought about by the discoloration of fully developed seeds through weathering. The majority of the brown seeds found in most well dressed samples belong to the latter class, whereas the greater proportion of the immature, shrivelled browns find their way into the tailings.

It is obvious from what has already been said that the vexed question of the relative weights of purple and yellow seeds can only be solved either by direct breeding experiments or by comparing the weights of fully developed seeds from a large number of plants in one and the same variety. With this object in view, in 1925 fully ripe heads were harvested from a number of spaced plants of three different varieties grown under similar conditions. The seeds from each plant were placed according to their general colour in six arbitrary classes and weighed, with the result shown in Table VII. It should, however, be stated that although great care was taken in classifying the seeds, it is quite possible that some of the seeds placed in the yellow group may in fact be phenotypically purple seeds, as the purple pigment on the seeds of some of the plants was so extremely faint as to make accurate classification practically impossible.

* There is still another, but very rare, kind in which the brown coloration is not due to environmental conditions, but to the presence of certain genetical factors.

TABLE VII.—*The mean weights (gm. per 1000 seeds) of different coloured seeds from different plants within the same variety.*

Variety.	Yellow.			Faint purple.			Very light purple.			Light purple.			Purple.			Deep purple.		
	No. of plants.	Gm.	P.E.	No. of plants.	Gm.	P.E.	No. of plants.	Gm.	P.E.	No. of plants.	Gm.	P.E.	No. of plants.	Gm.	P.E.	No. of plants.	Gm.	P.E.
English broad red ..	24	1.86	±.055	11	1.85	±.048	13	1.64	±.031	13	1.78	±.034	9	1.82	±.047	—	—	—
English late	8	1.62	±.672	6	1.64	±.061	10	1.64	±.085	10	1.85	±.043	6	1.88	±.023	6	1.93	±.106
Altaswede	25	1.67	±.064	31	1.62	±.036	21	1.64	±.045	21	1.67	±.031	17	1.74	±.041	10	1.75	±.031

Compared in this way the results are by no means conclusive, in fact they are rather contradictory. In English broad red all the various classes were very similar in this respect with the exception of very light coloured seeds, which were slightly lighter in weight, but in Altaswede the purple and very purple seeds were on the average slightly heavier than the lighter coloured seeds, though the differences in relation to the probable errors are obviously too small to have any significance ; while in the case of English late the light purple, purple and deep purple seeds were appreciably and rather significantly heavier than those in the yellow to very light purple classes. The coefficients of correlation for the weight and colour of seeds computed for these three populations and for 31 English broad red and 19 English late plants harvested in 1921 were :—

Harvest year.	Variety.	No. of plants.	Coefficient of correlation.
1921	English broad red ..	31	+ .0399 ± .1211
	English late	19	+ .3228 ± .1419
1925	English broad red ..	70	+ .0745 ± .0807
	English late	37	+ .5481 ± .0786
	Altaswede	125	+ .1459 ± .0593

As seen from the values for r, while there seems to be a fairly definite correlation between the weight and colour of seeds of English late, particularly in 1925, there is only slight evidence of correlation in the case of Altaswede, and no evidence at all for English broad red.

Stapledon (1920) in his investigations on the colour and other characteristics of seeds of commercial samples of different origin has shown that Canadian and several other foreign red clovers have an appreciably larger proportion of yellow and light coloured seeds than the British clovers. Although the data are admittedly too meagre to permit of drawing any definite conclusions, the results considered below seem to suggest that the lighter colour of the seeds of many of the foreign varieties is largely due to the fact that they usually contain a much smaller proportion of brown seeds than the home-grown varieties.

In 1925 a quantity of seed of Montgomery red clover was sent to Canada to be grown on a farm near Edmonton. A crop of seed was taken in 1926. This was sown in 1927 and again harvested for seed in 1928. The seeds of the Canadian grown Montgomery red harvested in 1926 and 1928 have been compared in respect to their colour and weight with the seeds grown in Montgomeryshire in the same years and from the same original stock as that sent to Canada. A brief summary of these results is given in Table VIII.

The influence of the harvesting conditions on the quality of the resultant seed crops is very clearly brought out by the difference in the quality of the Canadian grown seeds. It appears that in 1926 the conditions before and during harvesting were very favourable ; as a result the seeds were of very high quality and gave a germination of 93 per cent. In 1928 on the other hand the weather during harvesting proved unusually wet—the crop lying on the ground for some considerable time, and this is reflected in the extremely poor quality of the seed, the germination being only 45 per cent. In both years the harvesting conditions for the home-grown Montgomery crops analysed in Table VIII were by no means good, as indicated by the high percentage of brown seeds they contained. It should, however, be explained that those seeds which were

TABLE VIII.—*A comparison between the seed of Montgomery red clover once and twice grown in Canada and that grown in Montgomeryshire in respect of seed colours and weights.*

Seed colour.	Seeds harvested in 1926.						Seeds harvested in 1928.					
	Percentage number of seeds of different colours.				Weight per 1000 in gm.		Percentage number of seeds of different colours.				Weight per 1000 in gm.	
	Including brown seeds.		Not including brown seeds.				Including brown seeds.		Not including brown seeds.			
	Canada.	Mont-gomery.	Canada.	Mont-gomery.	Canada.	Mont-gomery.	Canada.	Mont-gomery.	Canada.	Mont-gomery.	Canada.	Mont-gomery.
Deep purple ..	26.1	20.6	30.8	38.7	1.76	1.83	15.3	15.0	26.2	25.6	1.884	1.886
Light purple ..	33.3	16.5	39.2	31.1	1.69	1.67	28.0	24.7	47.8	42.1	1.815	1.829
Yellow	25.4	16.0	30.0	30.2	1.53	1.46	15.2	18.9	26.0	32.3	1.674	1.668
Brown	15.2	46.9	—	—	1.45	1.30	41.5	41.4	—	—	1.476	1.526
Total	100	100	100	100			100	100	100	100		

The average weights (gm. per 1000 seeds) of the samples were :—

1926.		1928.	
Canada.	Montgomery.	Canada.	Montgomery.
1.563	1.506	1.657	1.666

received direct from the growers had not been carefully dressed and therefore contained larger proportions of brown seeds than if they had passed through the hands of seed cleaners.

If the 1926 figures are examined it is evident that the Canadian grown seed taken as a whole contains a much larger proportion of light purples and yellows than the home-grown seed, and that its lighter colour is almost entirely due to the fact that it contains a much smaller proportion of brown seeds. Since it is impossible to determine their true colour, the brown seeds should not be included in the comparison. If they are omitted it will be seen that there is practically no difference in colour between the samples, though the Canadian sample appears at first sight to be lighter in colour. The data for the seeds harvested in 1928 also show that there are no significant differences either in colour or in weight between the home grown and Canadian grown Montgomery red seed. The following figures give the percentage frequency distributions for seed colours for 181 plants of American medium and 195 plants of English broad red grown under similar conditions at the Plant Breeding Station Farm:

	Yellow.	Faint purple.	Very light purple.	Light purple.	Purple.	Deep purple.
American medium ..	22.6	10.0	11.3	14.3	18.2	23.6
English broad red ..	24.1	11.8	19.0	19.0	15.4	10.7

Unfortunately no determinations were made on the original samples, but it was fairly evident from general observations that the seeds of American medium, as in the case of most samples received from the United States, appeared to be perceptibly lighter in colour than those of the English broad red. As is shown, however, by the above figures the American medium seeds grown under our conditions were on the average rather more deeply coloured than those of the native variety—a fact which proves that any difference in colour that may have existed between the seeds of the original samples was not inherited.

Hard Seeds.

In most samples of red clover a number of seeds may be found which, though perfectly normal and healthy, are incapable of germination simply because their seeds coats are impermeable to water. Under normal storage conditions most of these hard seeds will generally remain dormant for a very large number of years. Even under soil conditions, as the investigations of Grimm (1928) and others have shown, they germinate very slowly—many remaining inactive for a considerable period. If, however, the seed coats are abraded or in some other way injured so as to allow water to pass through—a very minute scratch is quite sufficient—the seeds will at once germinate and produce strong normal seedlings.

Different samples vary greatly in regard to the proportion of hard seeds they contain. While some samples contain no hard seeds, others may have 10 to 15 per cent. An occasional sample may have as much as 30 to 40 per cent. It is generally believed that the proportion of hard seeds in a sample depends partly on the variety and partly on the soil and climatic conditions under which the seeds are grown. Though it is possible that the relative number of hard seeds in an unthreshed crop may be influenced to a small degree by these factors,

TABLE IX.—*The average percentage germination results given by the seeds of a number of plants which had been thrashed in such a way as not to damage the testæ.*

Stage of ripeness of heads.	Seed quality.	No. of plants.	Germination.		Hard seeds.		Germination + hard seeds.		Dead.		Energy.*	
			Per cent.	P.E.	Per cent.	P.E.	Per cent.	P.E.	Per cent.	P.E.	Per cent.	P.E.
Ripe.	Good colour ; plump ..	30	55.5	±2.26	41.2	±2.26	96.7	±3.23	3.3	±0.319	31.2	±1.86
	Brown ; plump ..	10	66.4	±2.82	8.1	±1.91	74.5	±3.75	26.5	±4.99	48.3	±3.05
Under-ripe.	Good colour ; plump ..	10	70.6	±2.88	23.1	±2.93	94.7	±0.67	5.3	±0.63	43.1	±3.10
	Brown ; shrivelled ..	10	21.8	±2.93	0.15	±0.06	21.9	±2.96	78.1	±2.93	18.0	±2.88

* After 5 days germination.

it can be stated categorically that the proportion in a threshed sample depends almost entirely on the extent to which the seeds have been rubbed during the process of hulling : the closer within limits the concave is set to the hulling cylinder the fewer the number of hard seeds.

In order to determine whether the proportion of hard seeds varies in different individuals, fully ripe heads were harvested in 1921 from 21 plants of English broad red. The seeds were rubbed out by hand and germinated. The average percentage results were :—

Percentage germination in 10 days.	Percentage hard seeds. Mean.	Range.
82.2	14.2	1—45

This experiment was repeated in 1922 on 30 spaced plants of Montgomery late. From ten of these plants under-ripe as well as ripe heads were harvested. In these tests much greater care was taken than in 1921 not to abrade or in any way injure the testæ ; each seed was carefully teased out from its pod by means of two pairs of fairly blunt forceps. The seeds of each plant were divided into two classes, in the case of the ripe heads into (1) plump seeds of good colour, and (2) brown, plump seeds, and in the case of under-ripe heads into (1) plump seeds of good colour, and (2) brown, shrivelled seeds. All the seeds which did not fall within these classes were discarded. For each plant 400 or 500 seeds of Class 1 and 200 or 300 of Class 2 in lots of 100 each were germinated in a Copenhagen incubator for 12 days. The average results are shown in Table IX, p. 85.

One inference that can safely be drawn from the results given in Table IX is that the proportion of hard seeds in a carefully hand threshed sample depends very largely on the condition and stage of development of the seeds when harvested. While the brown, shrivelled seeds from the under-ripe heads gave practically no hard seeds, the bright, plump seeds from the same heads contained on the average 23.1 per cent. hard seeds. The highest proportion was given by the bright, plump seeds from fully ripe heads ; these had on the average as much as 41.2 per cent., that is, more than five times as many as the brown, plump seeds from the same heads, and nearly twice as many as the bright, plump seeds from under-ripe heads.

As the figures below, representing the frequency distribution of the percentage of hard seeds, indicate, the proportion of hard seeds varied greatly in different plants. In the case of the bright, plump seed from ripe heads it ranged from 12.6 to 70.4 per cent.

Per cent. hard seeds.	10—20	21—30	31—40	41—50	51—60	61—70	71—80
No. of plants ..	3	5	5	4	4	3	1

Despite the wide differences exhibited by the plants in regard to this character, it is a noteworthy fact that even the plants with the lowest percentage number of hard seeds had considerably more than is generally found in commercial samples after they have been threshed. Similar differences have been reported by Witte (1928) in Sweden, and Harrington (1915) in Canada.

A considerable amount of data bearing on the question of hard seeds in red clover has been obtained indirectly from the writer's breeding material. From

1922 onwards a large number of seeds—the progeny of hundreds of individual plants that have been crossed during the previous summers—have been sown in boxes every spring. It was soon found that these seeds germinated very unevenly unless they had been previously treated. In many cases as much as 60 to 70 per cent. of the seeds remain dormant for several weeks. It has even been necessary in the case of some important crosses to take up the hard seeds laboriously one by one from the soil in order to puncture their seed coats with a needle. The seeds treated in this manner invariably germinated within a few days, producing strong healthy seedlings. For rubbing out small lots of seeds a simple but very effective little apparatus is used. This consists of two well made open wooden boxes 12 inches by 24 inches in size, one of which fits into the other. The upper box, in which the heads are placed, has wooden sides about 6 inches high and wire gauze across the bottom. A small hand appliance lined with corrugated rubber is employed for rubbing the heads against the wire gauze through which the seeds drop into the lower box. Boxes with wire gauze of different sized mesh are used for different species according to the size of the seeds. For red clover and lucerne, wire gauze with 12 meshes to the linear inch has been found to be most effective, while for white clover and *Lotus* species, gauze with 14 meshes to the linear inch has given every satisfaction.

Despite the fact that the seeds threshed in this way are subjected to fairly severe rubbing between the wire gauze and the rubber, most samples contain a high proportion of hard seeds, in many cases as much as 60 to 70 per cent. Various methods of reducing the number of hard seeds in hand threshed samples have been tried. For instance, in 1927, 1928 and 1930, different portions of samples which had been rubbed out by means of the hand thresher were subjected to the following treatments: (1) control—not treated; (2) shaken in a box completely lined with sand-paper; (3) lightly rubbed between two sheets of sand-paper; (4) fairly vigorously rubbed between sand-paper, and (5) testa of each seed punctured with a sharp needle. These seeds were then tested for germination. The average percentage number of hard seeds for each treatment after 10 days test was :—

	(1) Control; not treated.	(2) Shaken in a box lined with sand-paper.	(3) Lightly rubbed between sand-paper.	(4) Fairly vigorously rubbed between sand-paper.	(5) Punctured with a needle.
1927 ..	69	59	21	5	No test.
1928 ..	40	10	7	4	0
1930 ..	44	No test.	3	1	0

The most effective treatment was that of making a small puncture in the seed coats by means of a needle, but this method is much too laborious for general use. The method which has been employed for the last seven years, and one which has given general satisfaction, consists in rubbing the seeds fairly

vigorously between two sheets of fairly coarse sand-paper. This method, though not quite so effective, has a great advantage over the sulphuric acid treatment recommended by Love and Leighty (1912) and now used by most workers, in that it not only entails far less work—an important consideration when dealing with a large number of samples—but also that there is far less risk of damaging the seeds.

Before leaving the question of hard seeds, it may be mentioned that white clover, lesser and greater birdsfoot trefoil (*Lotus corniculatus* and *L. major*), hop trefoil (*Medicago lupulina*), lucerne and subterranean clover have been found to behave very similarly to red clover in regard to hard seeds. The fully developed seeds of all these species (and very probably of a number of other leguminous species as well) contain a very high proportion of hard seeds when harvested.

Relation between germination capacity, germination energy, number of hard seeds and weight of seeds.

The coefficients of correlation for the various seed properties enumerated above were computed from the data obtained on the seeds of the 30 single plants harvested in 1922, and these have been summarized in Table IX, p. 85. Although the number of plants upon which the data are based are admittedly too small to allow of definite conclusions being drawn, the results obtained are suggestive. The data for germination, hard and dead seeds were based on 12 day tests, while the figures for the germination energy represented the number of seeds that had germinated during the first five days of the tests.

(*a*) The very high negative coefficient of correlation that existed for the percentage number of hard seeds and percentage germinations was so obvious that it was not calculated. In every sample of good seeds the percentage germination varied inversely to the percentage number of hard seeds present.

(*b*) That there was a close negative correlation between percentage number of hard seeds and percentage energy is clearly indicated by the value of r, $-.8619 \pm .0285$, obtained for these two variants.

(*c*) There was no relation between percentage number of hard seeds and the weight of the seeds; the coefficient of correlation in this case was $+.0295 \pm .1230$.

(*d*) In the case of poor samples containing more than 20 per cent. dead seeds there was a close negative correlation between percentage energy and the percentage number of dead seeds, the coefficient of correlation being $-.9211 \pm .1430$.

(*e*) In the case of well-developed samples with less than 20 per cent. dead seeds there was, however, a fairly strong positive correlation between energy of germination and number of dead seeds; the coefficient of correlation in this case was $+.4452 \pm .0937$.

It is generally assumed that a high initial rate of germination as shown by the percentage energy figures is a fairly good indication of the quality of the seed, that is, the higher the rate of germination the better the quality. The correlation coefficients given above strongly suggest that though this is true for poor samples with very low germination, it is not true in the case of samples of good or even moderately good quality; in fact the results seem to

point in the other direction, that a rapid initial rate of germination is an indication of poor quality seed. The reason for this is quite clear. The rate of germination of normally healthy seeds is very largely governed by the rate at which water penetrates the seed coat, and since, as already shown, the testæ of well developed, bright, plump seeds are on the average much more impermeable to water than those of under-developed or discoloured seeds, the rate of germination of good quality seeds must be correspondingly slower.

The coefficients of correlation for the percentage energy and seed weights for samples with less than 20 per cent. dead seeds and with 20 per cent. or more dead seeds were $+ .0299 \pm .1156$ and $- .0734 \pm .1225$ respectively, indicating that there was no connection between rate of germination and size of the seeds.

SUMMARY.

The results of the investigations described in this paper are briefly summarized below :—

(1) Owing to the wide range in the time of flowering of the different plants within each variety and of the various heads within the individual plants, it has been shown that red clover seed crops ripen very unevenly ; some of the heads being fully ripe before others were in flower.

(2) The rate of development of the seeds depends to a large extent on the time of the year the flowers are pollinated. Under Aberystwyth conditions the flowers pollinated during the second week in July were fully ripe within 34 to 38 days of pollination.

(3) The best quality seeds as indicated by their general colour, weight and germination capacity were obtained from heads in which all the calyces were entirely brown, while the upper parts of the stems were of a yellowish green colour (stage II). Stages I, III and IV described on page 66 also gave a high proportion of seeds of good quality, while all the other stages in which the heads were still green gave in comparison very poor quality seeds. Crops should, therefore, be cut about 5 to 6 weeks after the period of full bloom, when the greatest number of heads are in stages I to IV, in order to obtain the maximum yield of seed of good quality. It has been computed that even if the crops are cut at the optimum stage, only about 50 to 60 per cent. of the total heads harvested will produce seed of commercial value.

(4) If the crops are allowed to become over-ripe and wet weather intervenes, the ripe seeds soon become discoloured : brown seeds of this nature generally have low germination capacity. Under unfavourable harvesting conditions there is also a great risk of losing a considerable proportion of the crop, when over-ripe, through shedding and sprouting.

If, on the other hand, the crops are cut before they are ripe, that is, when most of the heads are still entirely green, a large proportion of shrivelled and small seeds of poor colour and low germination will be obtained.

(5) Some varieties and nationalities were found to have consistently heavier seeds than others. Chilian and New Zealand had the heaviest, and wild red and Cornish marl the lightest seeds. There was but very little difference in regard to seed weights between English broad red, English late, Vale of Clwyd, Czecho-

slovakian, Swedish late, French and Brittany. The seeds of American medium and American Mammoth, Canadian, Italian and Montgomery were, however, appreciably lighter in weight. The seed weights showed very marked seasonal variation, and even during the same season different samples of the same varieties often exhibited very pronounced differences in this respect.

(6) The weight of the seeds of individual plants within a variety was found to be extremely variable.

(7) In the case of seeds of good quality there seemed to be no definite connection between colour and weight. Brown seeds were, however, appreciably lighter in weight than both purple and yellow seeds.

(8) Individual plants vary within wide limits in respect to the proportion of hard seeds produced. In 1922, for example, the number of hard seeeds in 30 fully ripe samples harvested from individual plants ranged from 12.6 to 70.4 per cent. of the total, while the average for all the plants was 41.2 per cent. The proportion of hard seeds actually produced by a particular plant depends to a large extent on the stage of ripeness and condition of the seeds. Good quality seeds from under-ripe heads had on the average 23.1 per cent., brown seeds from ripe heads 8.1 per cent., and brown seeds from under-ripe heads 0.15 per cent. hard seed.

Most of the hard seeds germinated quite readily after they had been rubbed between sand-paper.

(9) In the case of seeds of good quality there was a close negative correlation between the number of hard seeds on the one hand and the percentage energy and final germination on the other, and a fairly close positive correlation between energy of germination and the number of dead seeds.

In the case of poor samples of low germination capacity there was a close negative correlation between the number of dead seeds and percentage energy.

There was no correlation between size of the seeds, as indicated by weight, and the germination energy.

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